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11 August 1994

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Science & Technology

Japan

Development of Cogeneration Technologies

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Japan: Development of Cogeneration Technologies

Creating and Promoting a Pro-Environment Energy Community

94FE0480A Tokyo ENERGY in Japanese 1 Feb 94 pp 26-30

[Article by Kazuya Kawamoto, Assistant Section Head of the Agency of Natural Resources and Energy's Section for Energy Policies on Conservation and Alternative Energy. First of eight articles in the special issue on "City Gas Companies Putting Efforts Into Cogeneration"]

[Text]

Enacting Legislation for Improving the Energy Supply and Demand Structure

The goal of "targeting alternative energy supplies" is restricting the annual rate of final energy consumption to 1.4 percent by 2000. However, recent energy consumption has shifted to higher levels, and if we take the result of this pace into consideration, that goal will be extremely difficult to achieve (energy consumption will increase an average of 1 percent a year between now and 2000).

In order to create a stable and appropriate energy supply and demand structure that responds to changes in Japan's economic and social environment, which revolve around energy and cause this remarkable increase in energy consumption, we need to expand measures for rationalizing energy use and adopt measures that promote the introduction of alternative sources of energy (petroleum substitutes). Therefore, in March 1993 (the 126th Diet Session), legislation was enacted for improving the energy supply and demand structure (consisting of "Law for Rationalizing Energy Use," "Law for Promoting Development and Introduction of Alternative Energy," and "Special Accounts Act for Coal, Petroleum, and Alternative Energy," a revision of the Special Accounts Act for Coal, Petroleum, and Improving Energy Supply and Demand Structure).

Policy Aims

As part of a comprehensive energy conservation policy, it is vital that we strengthen measures that improve energy efficiency, which affects the entire energy system from supply to final consumption, as well as the social system.

Two-thirds of Japan's total primary energy supply (converted to crude oil, approximately 500 million kiloliter) is lost; if the ratio of useful energy to energy lost (35 percent to 65 percent) is changed by only 1 percent, annual energy savings of 14 million kiloliter is possible. This statistical conclusion reflects the current energy system, in which inputs of primary energy are separated in order to create secondary energy, such as electricity and heat, which are necessary as final consumption.

Based on the observations above, we could put efforts into maximum utilization of regional waste heat and other surplus energy; that is, into establishing a system that generates as much electricity as possible prior to heat generation and utilizes the heat produced when electricity is generated, or creating an energy system that combines heat use in stages. In concrete terms:

1. Because there are limits to the distance heat can be transported, due to adiabatic loss and other factors, measures for utilizing waste heat after power generation can take two directions: locating the demand around existing large-scale thermal power plants, or locating decentralized power sources that can supply both heat and electricity around demand areas.

Fig. 1
第1図 日本のエネルギーフロー

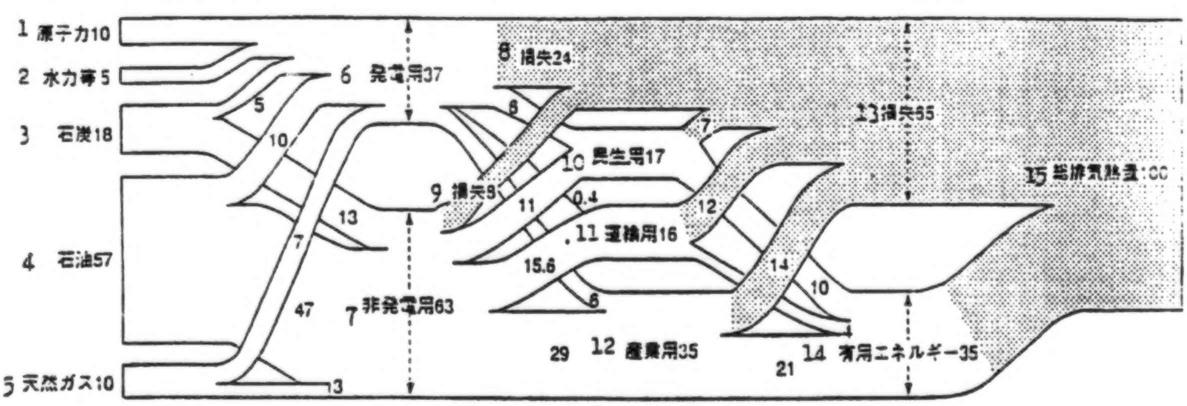

Figure 1. Japan's Energy Flow

Key: 1. Nuclear power 2. Hydroelectric power 3. Coal 4. Oil 5. Natural gas 6. Used to generate electricity 7. Not used to generate electricity 8. Lost 9. Lost 10. Used by the public sector 11. Used by transportation 12. Used by industry 13. Lost 14. Useful energy 15. Total volume of waste heat

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2. A boiler, the general apparatus for producing heat, that supplies steam of 200°C with a heat of combustion of 1500°C is a system that does not utilize the temperature difference of 1500° to 500°C that enables power generation and can effectively utilize this surplus energy through cogeneration.

These are being considered, and the establishment of an energy system that conserves energy will be promoted through large-scale regional cogeneration heat supply facilities, industrial parks utilizing cascades, high efficiency facilities for generating electricity from refuse, and facilities that supply and utilize surplus energy such as power plants and factories.

In addition, systematic provision of this kind of conservation-oriented energy system is effective when it is an integral part of other municipal structures; for example, organic coordination of roads and green space, the waste collection and disposal system, and placement of buildings so that the effects of natural cooling is taken into account. We are working to promote the formation of a "Pro-Environment Energy Community" as a so-called systemization policy that takes these points into consideration.

At the present time, making the most of surplus energy has a strong public infrastructure side (such as providing heat supply pipelines) and is not intrinsically profitable. Because we cannot expect adequate progress by handing over the responsibility to private efforts based on economic rationality, it is vital that we adopt systematic, stable measures as an energy policy.

Policy Details

Concrete Details on the Pro-Environment Energy Community

In order to build a regional system that efficiently utilizes energy, we are promoting the following energy system facilities, in which heat use from high to low temperature areas and power generation can be combined depending on regional characteristics.

1. Large-scale regional cogeneration heat supply facilities: These energy efficient systems supply heat from the waste heat produced by gas turbine generators of a suitable size, in order to maximize the capabilities of cogeneration (providing heat and electricity at the same time).
2. Industrial Parks Using Cascades: These systems utilize the heat in stages, from high temperature to low temperature areas, between a number of factories.
3. High Efficiency Facilities for Generating Power From Refuse (Facilities Using Energy from Waste): These systems extract energy from waste matter very efficiently; for example, the so-called repowering system that raises efficiency by using the waste heat from gas turbine power generation and increasing the temperature of the heat obtained by incinerating refuse, and the RDF (refuse derived fuel) system which turns waste matter into solid fuel and supplies electricity and heat.
4. Supply Facilities Near Power Plants and Factories With Surplus Energy: These systems utilize the steam produced by power plants and factories during processing, and supply heat to surrounding public demand.

第2図Fig.2

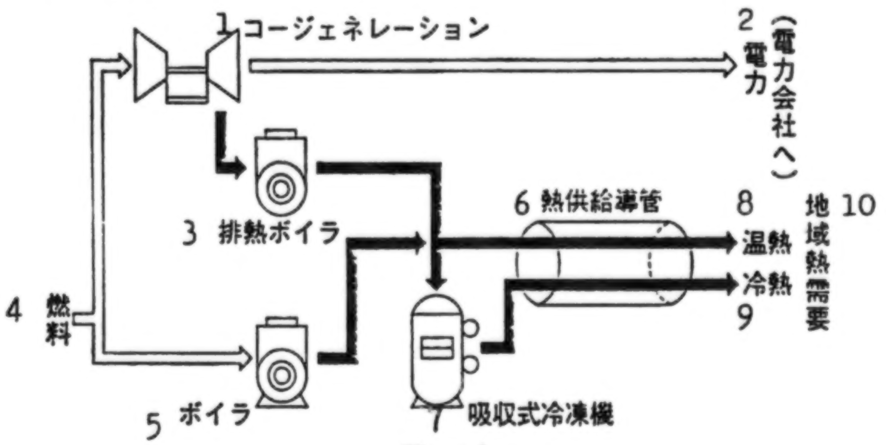

Figure 2.

Key: 1. Cogeneration 2. Power to utility companies 3. Waste heat boiler 4. Fuel 5. Boiler 6. Heat supply pipe 7. Absorption refrigerator 8. Warm 9. Cool 10. Regional heat demand

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第3図 Fig.3

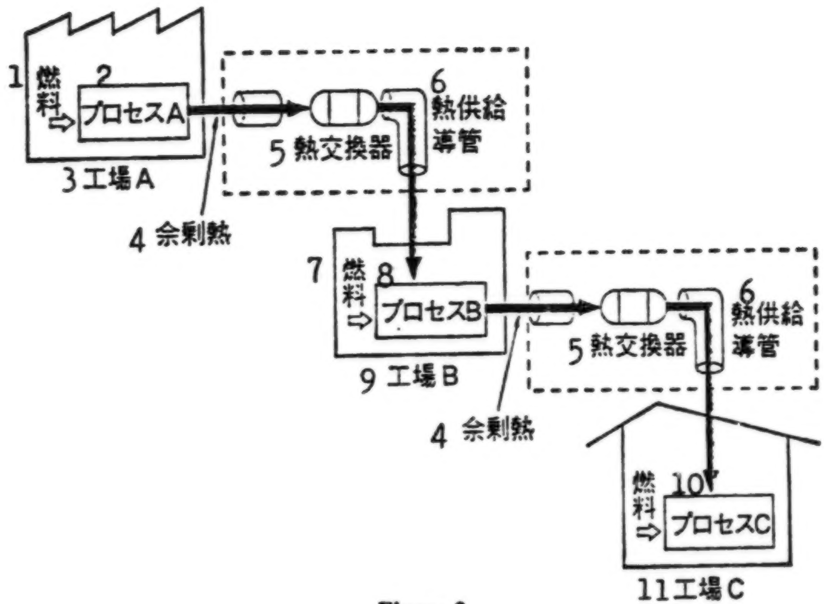

Figure 3.

Key: 1. Fuel 2. Process A 3. Factory A 4. Surplus heat 5. Heat exchanger 6. Heat supply pipe 7. Fuel 8. Process B 9. Factory B 10. Process C 11. Factory C

第4図 Fig.4

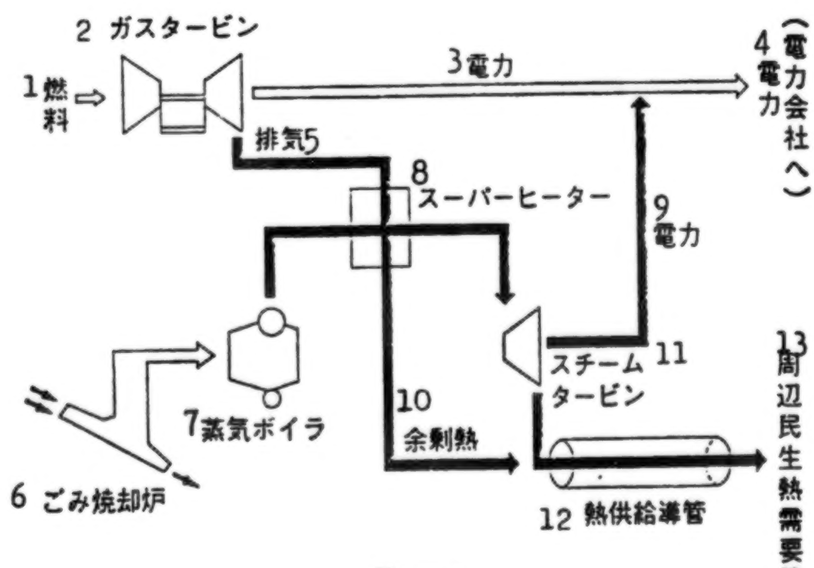

Figure 4.

Key: 1. Fuel 2. Gas turbine 3. Power 4. Power (to utilities) 5. Exhaust 6. Incinerator 7. Steam boiler 8. Super heater 9. Power 10. Surplus heat 11. Steam turbine 12. Heat supply pipe 13. Neighboring public heat demand

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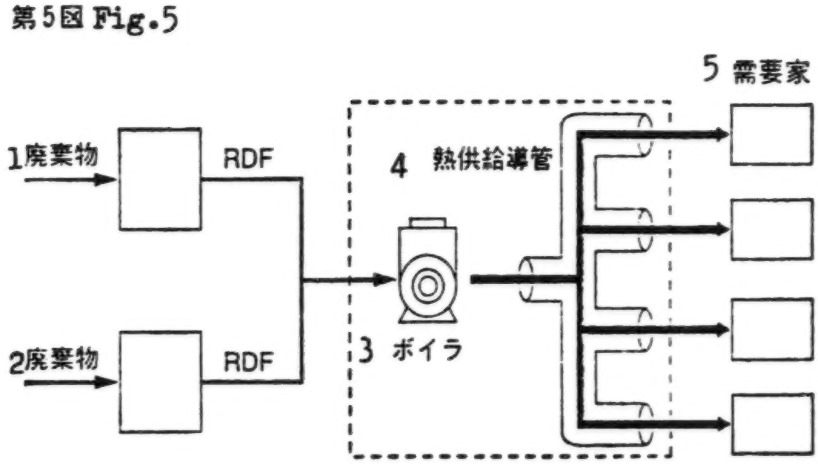

Figure 5.

Key: 1. Refuse 2. Refuse 3. Boiler 4. Heat supply pipe 5. Demand

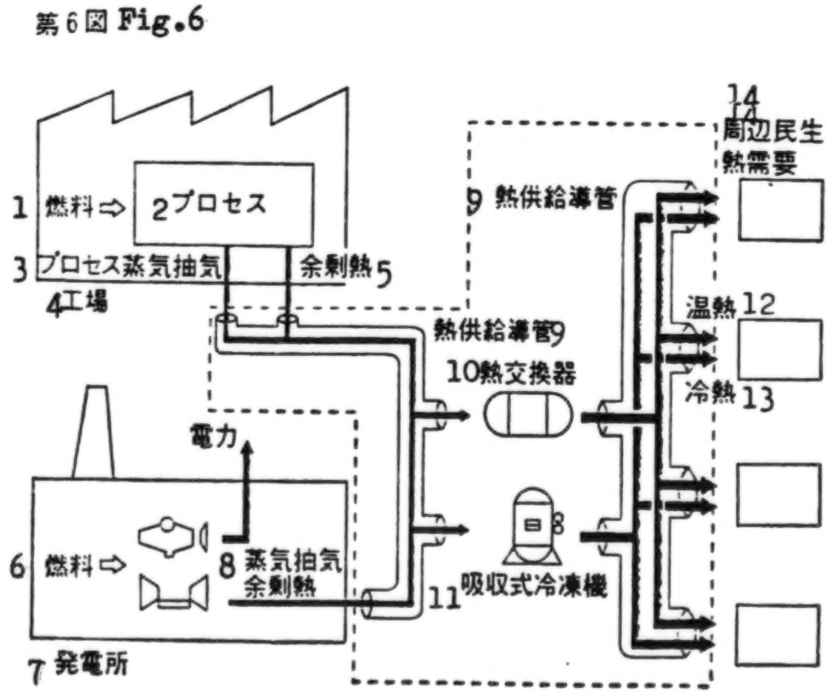

Figure 6.

Key: 1. Fuel 2. Process 3. Processing steam extracted 4. Factory 5. Surplus heat 6. Fuel 7. Power plant 8. Steam extracted, surplus heat 9. Heat supply pipe 10. Heat exchanger 11. Absorbtion Refrigerator 12. Warm 13. Cool 14. Neighboring public heat demand

Details of Aid Measures (budgeted for fiscal 1993)

1. Subsidies for Model Projects:

- Fossil Fuels Special Account: ¥4.466 billion
- Electricity Special Account: ¥156 million

Efforts will be made to improve facilities through cost reductions and technical advances, by means of data feedback and demonstrated results from leading model projects. Rate of subsidy: 15 percent (with an upper limit of ¥4 billion/year for each item targeted for aid).

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2. Subsidies for Project Feasibility Studies:

- Fossil Fuels Special Account: ¥359 million
- Electricity Special Account: ¥30 million

Aid for feasibility studies on topics such as economy and optimal energy income and outgo, for possible introduction of a supply system that utilizes energy efficiently. Rate of subsidy: a fixed sum (¥30 million); Number of items: 12 (fossil fuel account) + 1 (electricity account)

3. Commissioning a Basic Survey:

- Fossil Fuels Special Account: ¥163 million

A survey will be conducted for examining new types of energy conservation and the various peripheral elements (such as, urban planning and institutional issues) related to providing a system, and for the potential for resource allotments. Note: the Electricity Special Account only targets high efficiency facilities for generating power from refuse (facilities utilizing energy from waste).

Organization

1. Aid Per Project

Project costs will be subsidized for items such as large-scale regional cogeneration heat supply facilities, industrial parks utilizing cascades, high efficiency facilities for generating power from refuse, and supply facilities utilizing surplus power, such as power plants and factories.

Project Subsidies:

- Improved Measures from Fossil Fuels Special Accounts: ¥4.466 billion
- Various Measures from Electricity Special Account: ¥156 million (Subsidy rate: 15 percent; upper limit of subsidy per targeted project: ¥4 billion/year)

第7図 Fig.7

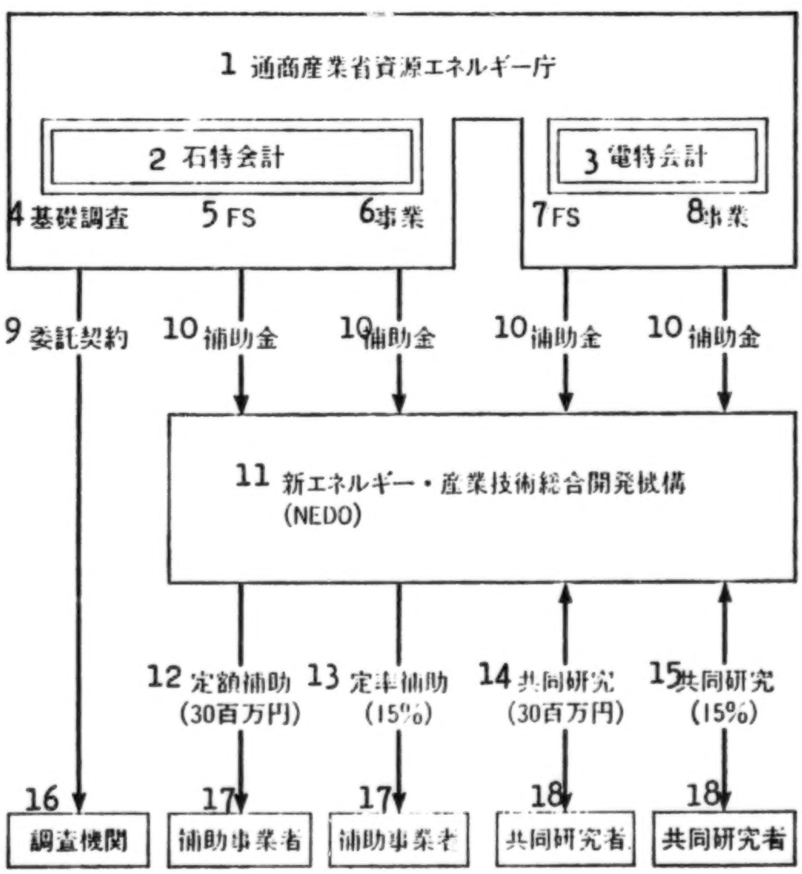

Figure 7. Subsidy Scheme

Key: 1. Agency of Natural Resources and Energies, MITI 2. Fossil Fuels Special Account 3. Electricity Special Account 4. Basic survey 5. Feasibility study 6. Projects 7. Feasibility study 8. Projects 9. Commissioned contract 10. Subsidy 11. New Energy and Industrial Technology Development Organization (NEDO) 12. Fixed subsidy (¥30 million) 13. Fixed percentage subsidy (15 percent) 14. Joint research (¥30 million) 15. Joint research (15 percent) 16. survey organizations 17. Subsidized enterprises 18. Joint research institutions

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2. Aid Per Project Feasibility Study

Costs for feasibility studies will be subsidized for items such as large-scale regional cogeneration heat supply facilities, industrial parks utilizing cascades, high-efficiency facilities for generating power from refuse, and supply facilities utilizing surplus power such as power plants and factories.

Project Subsidies:

- Improved Measures from Fossil Fuels Special Accounts: ¥360 million
- Various Measures from Electricity Special Account: ¥30 million (Subsidy rate: fixed sum; number of items targeted: 12, Fossil Fuels Account and 1, Electricity Account)

3. Commissioning a Basic Survey

In order to promote the creation of a "Pro-Environment Energy Community," we will examine, among other things, just what an organized facility should be: one that coordinates a conservation-oriented energy supply system with the integral parts of the municipal structure, such as waste collection and disposal, placing buildings so that natural cooling circulation is taken into account, and providing green space.

Furthermore, in order to provide the basic data which is a prerequisite for promoting a "Pro-Environment Energy Community," regions possessing an area undergoing redevelopment will be selected nationwide, and existing surplus energy conditions, such as the location of waste heat sources and refuse and the distribution of natural energy, and appropriate estimates of regional energy demands will be studied.

Cost of improved measures from Fossil Fuels Special Account: 162 million yen

- Vision planning: seven targeted items (12 million/item)
- Concept study: two targeted items (26 million/item)
- Basic surveys on resource allocation: two targeted projects (13 million/project)

Policy Results

Promoting the creation of the Pro-Environment Energy Community will be a mid- to long-term plan. It is conceived as a so-called systemization plan that looks at facilities coordinated with other elements of the municipal structure; it also has a basic infrastructure that is weak in terms of intrinsic profitability but strong in terms of public service, such as providing heat supply pipelines.

1. Example of Energy Efficient Calculation: If we perform calculations for a large-scale regional cogeneration heat supply system as an example of a conservation-oriented energy system, energy savings of 14 percent compared to existing supply methods can be achieved.
2. Anticipated Results of Energy Conservation: Through administrative guidance for promoting a conservation-oriented energy system, we can build a social system that limits the amount of primary energy investment to approximately one million kiloliters by fiscal year 2000.

第3図 Fig.8

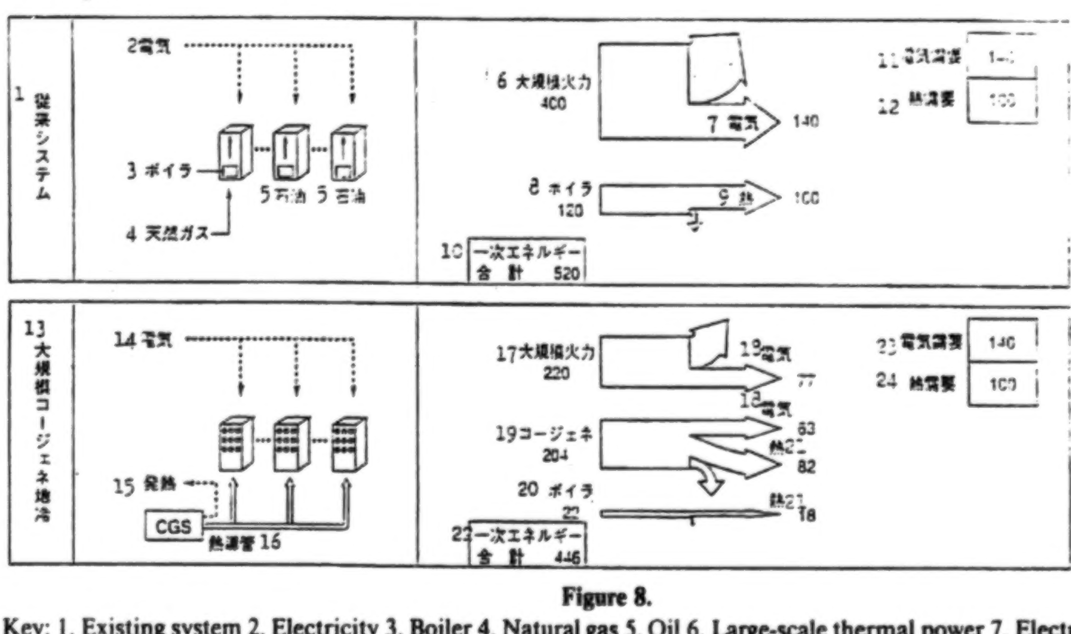

Figure 8.

Key: 1. Existing system 2. Electricity 3. Boiler 4. Natural gas 5. Oil 6. Large-scale thermal power 7. Electricity 8. Boiler 9. Heat 10. Primary energy total 11. Electricity demand 12. Heat demand 13. Large-scale cogeneration 14. Electricity 15. Heat generation 16. Heat pipeline 17. Large-scale thermal power 18. Electricity 19. cogeneration 20. Boiler 21. Heat 22. Primary energy total 23. Electricity demand 24. Heat demand

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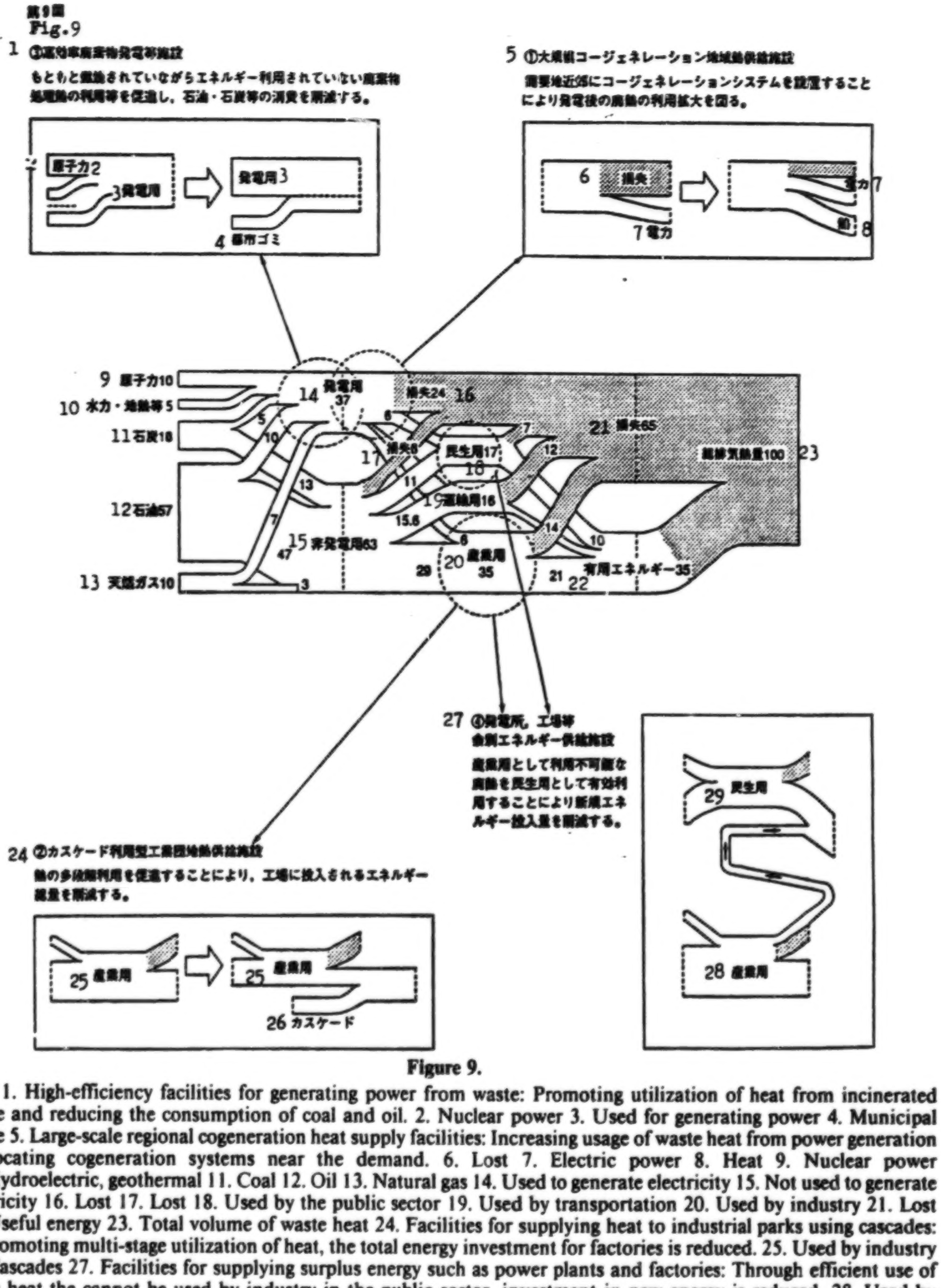

Figure 9.

Key: 1. High-efficiency facilities for generating power from waste: Promoting utilization of heat from incinerated refuse and reducing the consumption of coal and oil. 2. Nuclear power 3. Used for generating power 4. Municipal refuse 5. Large-scale regional cogeneration heat supply facilities: Increasing usage of waste heat from power generation by locating cogeneration systems near the demand. 6. Lost 7. Electric power 8. Heat 9. Nuclear power 10. Hydroelectric, geothermal 11. Coal 12. Oil 13. Natural gas 14. Used to generate electricity 15. Not used to generate electricity 16. Lost 17. Lost 18. Used by the public sector 19. Used by transportation 20. Used by industry 21. Lost 22. Useful energy 23. Total volume of waste heat 24. Facilities for supplying heat to industrial parks using cascades: By promoting multi-stage utilization of heat, the total energy investment for factories is reduced. 25. Used by industry 26. Cascades 27. Facilities for supplying surplus energy such as power plants and factories: Through efficient use of waste heat the cannot be used by industry in the public sector, investment in new energy is reduced. 28. Used by industry 29. Used by the public sector

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Present State of Development of 300kW Ceramic Gas Turbines for Industrial Use

*94FE0480B Tokyo ENERGY in Japanese
1 Feb 94 pp 31-34*

[Article by Yasukata Tsutsui, Energy Division's Hydraulic Engineering Section Head, Mechanical Engineering Laboratory, Agency of Industrial Science and Technology (MITI). Second of eight articles in the special issue on "City Gas Companies Putting Efforts Into Cogeneration"]

[Text] The development of a 300 kilowatt ceramic gas turbine (CGT) for industrial use began in October 1988 as a nine-year project, part of the Agency of Industrial Science and Technology's (AIST) Moonlight Project. At the present time, the former Sunshine, Moonlight, and Global Environment projects are being promoted in a unified New Sunshine Project. This project is developing three kinds of regenerative gas turbines with the goal of achieving at least 42 percent thermal efficiency. Fiscal 1993 is the mid-term evaluation year, and every engine manufacturer is preparing for trial operation of the basic CGT at turbine intake temperatures of 1,200°C.

Why Ceramic? Why 300kW?

Large gas turbines for jet engines and industrial use are cooled by air passing through the turbine's diaphragms and blades. By using blade cooling technology that makes heat from the high temperature gas, which covers the blade surface with an air film, difficult to transmit, the turbine intake temperature is raised and thermal efficiency improves every year. However, this cooling technology cannot be applied to small gas turbines with small blades, so raising the temperature and efficiency is difficult. The Ceramic Gas Turbine Project's goal is to overcome this obstacle and raise temperatures and efficiency by using ceramics, which remain strong even at high temperatures.

Ceramics differ from common metal materials and are known as fragile materials, and are easily broken when force is added to any internal flaws such as spaces. For example, if the ratio of internal defects per unit volume is constant, the ratio of internal defects increases per individual part as part size increases, and the part breaks easily when a load is added. In fact, if the part is big and difficult to produce, the percentage of internal defects per unit volume increases, and moreover, residual stress from forming and firing commonly arises, making it difficult to produce large ceramic parts.

For the small gas turbines described above, the goals shown in Table 1 were set after taking into account the difficulties of raising temperatures and efficiency and increasing the size of ceramics parts; we decided to develop 300kW gas turbines.

Table 1. Development Goals (Note: thermal efficiency is proportional to the gross shaft output of the engine with respect to the thermal input, which is based on the amount of low-grade heat generated from a fuel; this is set at 760mm Hg and 15°C under atmospheric conditions)

Item	Goals			
	Engine Efficiency	Turbine Intake Temperature	Shaft Output	Waste Gas Characteristics
Ceramic Gas Turbine	42% and up	1,350°C	300kW class	At or below legal standard
Ceramic Parts	Strength at High Temperatures (1,500°C)			Breakage Resistance
	Lowest certified strength 44MPa and below; Y coefficient 20 or below			15MPa($m^{1/2}$) and below

How Should the Project Develop?

As shown in Table 3 and following the development schedule shown in Table 2, the three national research institutes in charge of basic research and the New Energy and Industrial Technology Development Organization (NEDO) and engine and ceramics manufacturers that are in charge of development participated in project planning. At the present time three types of engines, the CGT301, CGT302, and CGT303 are being developed under the management of AIST's New Sunshine Planning and Promotion Center.

The CGT301 is a single shaft gas turbine consisting of a single-stage axial flow, single-stage centrifugal compressor, an axial flow double turbine, and a shell tube heat exchanger in which the high temperature portion is ceramic and the low temperature side is made of metal. The CGT302 is a double shaft gas turbine consisting of a single-stage centrifugal compressor, an axial flow single-stage gas generator turbine, an axial flow single-stage power turbine, and a metal plate fin type heat exchanger. The CGT303 is a double shaft gas turbine consisting of a single-stage centrifugal compressor, a radial single-stage gas generator turbine, an axial flow single-stage power turbine, and two rotating regenerative heat exchangers.

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Table 2
第2表 開発スケジュール

Table 2. Development Schedule

Key: 1. Research Objectives 2. Fiscal Years: 1988 to 1996 3. Research and Development of Heat-Resistant Ceramic Parts and Materials 4. Research on ceramic parts and materials and on parts technology 5. Research and Development of Elemental Technologies 6. Research on elemental technologies and research and development on constituent machinery (such as compressors, gas burners, turbines, heat exchangers, bearings, precision controls) 7. Design, Trial Manufacture, and Operations Research: (1) Basic Design; (2) Primary Research; (3) Secondary Research; (4) Tertiary Research 8. Basic design 9. Mid-term evaluation 10. Trial manufacture of the basic GT (900°C) 11. Trial manufacture of the basic CGT (1,200°C) 12. Trial manufacture of the pilot CGT (1,350°C) 13. Research on Social Compatibility: (1) Study of Environmental Preservation; (2) Study of Utilization Systems 14. Study of Environmental Preservation 15. Analysis of load configuration and study of economy and operations management

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Table 3

第3表 研究開発体制

1工業技術院ニューサンシャイン計画推進室

- 2工業技術院機械技術研究所
- 工業技術院名古屋工業技術研究所
- 科学技術庁航空宇宙技術研究所

3新エネルギー・産業技術総合開発機構（NEDO）

- 4コージェネレーション用再生1軸CGT：CGT301
  - 石川島播磨重工業（株）
  - 日本ガイシ（株）
  - 日本特殊陶業（株）
- 5コージェネレーション用再生2軸CGT：CGT302
  - 川崎重工業（株）
  - 京セラ（株）
  - 住友精密工業（株）
- 6可搬式発電用再生式2軸CGT：CGT303
  - ヤンマーディーゼル（株）
  - （株）新潟鉄工所
  - 京セラ（株）
  - 日本特殊陶業（株）
  - NKK
- 7（支援研究）
  - 8・耐熱セラミック部材の研究開発のうち
    - ①セラミック部材の信頼性確証試験の試験開発
      （財）ファインセラミックスセンター
    - ②セラミック部材接合技術の試験・評価方法の開発（社）日本溶接協会
  - 9・社会適合性研究
    （社）日本ファインセラミックス協会

Table 3. Organization of Research and Development

Key: 1. Agency of Industrial Science and Technology (AIST) New Sunshine Project Promotion Center 2. Mechanical Engineering Laboratory, AIST; Government Industrial Research Institute, Nagoya, AIST; and the Aerospace Technology Institute, Science and Technology Agency (STA) 3. New Energy and Industrial Technology Development Organization (NEDO) 4. Regenerative single shaft CGT for cogeneration: CGT301: Ishikawajima-Harima Heavy Industries, NGK Insulators, Ltd., and NGK Sparkplug Company 5. Regenerative double axle CGT for cogeneration: CGT302: Kawasaki Heavy Industries, Kyocera Corporation, and Sumitomo Precision Products Company 6. Regenerative double shaft CGT for portable power generation: CGT303: Yanmar Diesel, Niigata Engineering Company, Kyocera Corporation, NGK Sparkplug Company, and NKK 7. Research Support 8. For R&D on heat-resistant ceramic parts and materials: (1) Japan Fine Ceramics Center is developing tests for confirming reliability of ceramic parts and materials; (2) Japan Welding Association is developing tests and evaluation methods for ceramic parts and materials joining technologies 9. Social compatibility research: Japan Fine Ceramics Association

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The order of engine development is as shown in Table 2: the basic GT with metal parts and a turbine intake temperature of 900°C, the basic CGT using ceramic parts and having a turbine intake temperature of 1,200°C, and then a pilot CGT with a turbine intake temperature of 1,350°C. The various components of the pilot CGT, which is the ultimate goal, are shown in Table 4.

Table 4. Components for Each Engine

Name	CGT301	CGT302	CGT303
Fuel	Natural gas	Natural gas	CNG/kerosene
Output kW	300	300	300
Thermal efficiency %	42	42	42
Compressor pressure ratio	7.3	8	4.5
Turbine intake temperature	1,350	1,350	1,350
Output shaft revolutions per minute	3,000/3,600	3,000/3,600	3,000/3,600
Compressor Form:	titanium alloy single stage axial flow + centrifugal single stage	titanium alloy centrifugal single stage/intake blades	Titanium alloy centrifugal single stage
Insulating efficiency %	81.5	82	82.4
Revolutions per minute (RPM)	56,000	76,000	55,000
Turbine Form (CGT):	hybrid double stage axial flow	ceramic single stage axial flow	Ceramic single stage radial
Insulating efficiency %	87.5	84	88.3
RPM	56,000	76,000	55,000
Power Turbine Form:	—	Hybrid single stage axial flow/fixed nozzle	Hybrid single stage axial flow/adjustable nozzle
Insulating efficiency	—	88	86.8
RPM	—	57,000	32,500/39,000
Burner Form:	Ceramic single cylinder pre-mixed lean burn	Ceramic single cylinder pre-mixed lean burn	Ceramic single cylinder pre-mixed lean burn
Jet valve	Hybrid	Dispersion nozzle	Air assist
Efficiency %	99	99	99
Heat Exchanger Form:	Ceramic/metal shell & tube heat transfer	Inconel/inconel & stainless steel plate fin heat transfer	Rotary regenerator x 2
Temperature efficiency %	84.5	82	92
Gas temperature °C	825/386	823/390	972/274
Air temperature °C	281/740	296/717	200/908
RPM	—	—	20
Speed Reducer Form:	Parallel	Planetary + Parallel	Parallel
Speed reduction ratio	18.7/15.6	19.0/15.8	10.8

In addition, changes in the various engine components based on the basic GT, basic CGT, and pilot CGT development stages are shown in Table 5, using the CGT302 as an example. It is clear that a rise in output and improvements in thermal efficiency will accompany the increase in the turbine intake temperature.

Table 5. Engine Development Steps (CGT302)

Type	For double shaft cogeneration CGT302		
Gas Turbine	Basic GT (designed values)	Basic CGT	Pilot CGT
Fuel	Kerosene	Natural gas	Natural gas
Output kW	56	140	300
Thermal efficiency %	23	32	42
Air flow kg/s	0.53	0.68	0.89

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Table 5. Engine Development Steps (CGT302) (Continued)

Type	For double shaft cogeneration CGT302		
Output/Flow	106	206	337
Compressor Pressure Ratio	4.2	5.9	8
Turbine Intake Temperature	900	1,200	1,350
Output Shaft Revolutions per minute	(1,800)/2,160	(2,700)/3,240	3,000/3,600
Compressor Form:	Titanium alloy centrifugal single stage	Titanium alloy centrifugal single stage	Titanium alloy centrifugal single stage/intake blades
Insulating efficiency %	79	79	82
Revolutions per minute (RPM)	59,700	68,400	76,000
Turbine form (CGT):	Solid heat-resistant alloy single stage axial flow	Solid heat-resistant alloy single stage axial flow	Solid heat-resistant alloy single stage axial flow
Insulating efficiency	79	79	84
RPM	59,700	68,400	76,000
Power Turbine Form:	Solid heat-resistant alloy single stage axial flow/fixed nozzle	Hybrid single stage axial flow/fixed nozzle	Hybrid single stage axial flow/fixed nozzle
Insulating efficiency %	80	82	88
RPM	34,200	51,300	57,000
Burner Form:	Single cylinder, metal liner, diffusion burning	Single cylinder, ceramic liner, can change to premixed lean burn	Single cylinder, ceramic liner, can change to premixed lean burn
Jet valve	Dual coiled pressure jet nozzle	Dispersion nozzle	Dispersion nozzle
Efficiency %	99	99	99
Heat Exchanger Form:	Stainless steel plate fin heat transfer	Inconel plate fin heat transfer	Inconel/inconel & stainless plate fin heat transfer
Temperature efficiency %	79	78	82
Gas Temperature °C	633/299	797/391	823/390
Air Temperature °C	198/541	254/678	296/717

Present State of Development

During the initial stage of the project, shape precision for the CGT301's hybrid rotor blade and for the CGT303 scroll, in which satisfactory shape could not be attained due to deformations during firing, improved rapidly due to research and development already performed, which propelled ceramic parts manufacturing forward.

As for the ceramic parts incorporated into the basic CGT with a turbine intake temperature of 1,200°C, cold spin and hot spin tests are currently being performed on the moving and stationary blades, and steady progress is being made on heat impact testing of stationary parts such as scrolls, nozzles and ducts. These are being inserted into the engine piece by piece. While test runs for confirmation are moving forward, final preparations are continuing for a verification run at a turbine intake temperature of 1,200°C.

In addition, evaluation of the proposed materials for the pilot CGT with a turbine intake temperature of 1,350°C, now in the testing stage, is continuing at the Government Industrial Research Institute (GIRI), Nagoya, and the Fine Ceramics Center.

Figure 1 shows a cutaway model of the CGT301, and Figures 2 and 3 show the main ceramic parts for the CGT302 and CGT303.

Towards Verification of Operation at a Turbine Intake Temperature of 1,200°C

As initially stated, this fiscal year is the year for the project's mid-term evaluation. The purpose of the mid-term evaluation is to assess the results of research and development and to improve the way research and development is progressing. Verifying operation at a turbine intake temperature of 1,200°C has become the most difficult subject of evaluation. Each group described above is continuing with cold and hot spin tests on the moving ceramic blades, and heat impact tests on the stationary parts, and these ceramic parts are inserted into the engine in order, which is the final step towards verifying operations at 1,200°C. We hope for a solution through the efforts of the members of each group.

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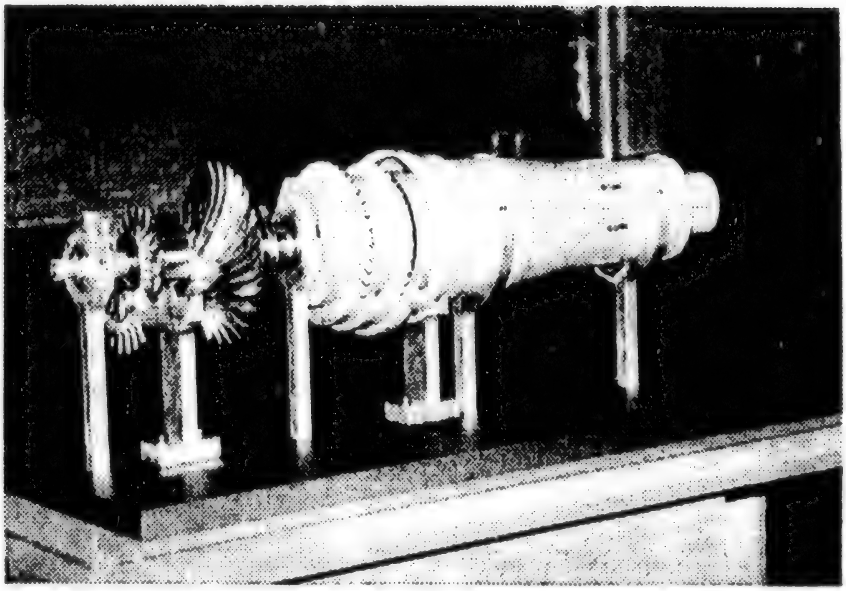
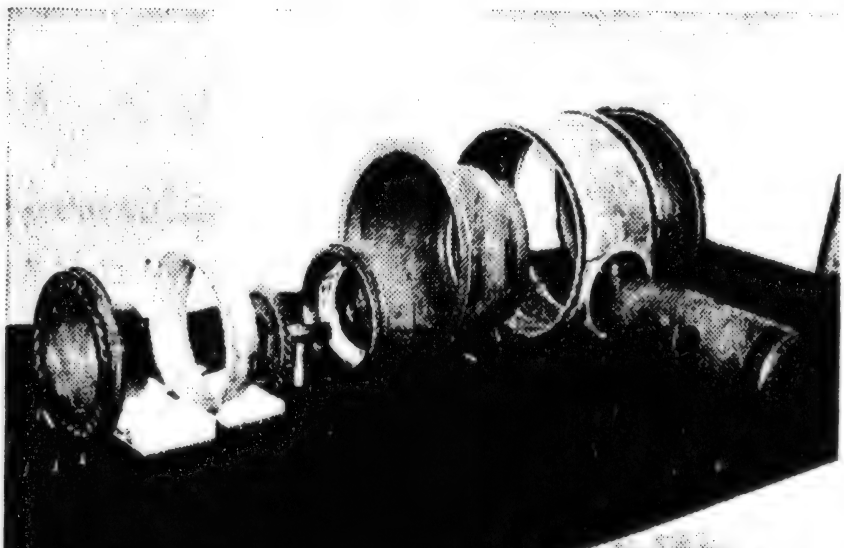


第1図　CGT301のカットモデル
Fig.1
Figure 1. CGT301 Cutaway Model



第2図　CGT302の主なセラミック部品
Fig.2
Figure 2. Main Ceramic Parts for the CGT302

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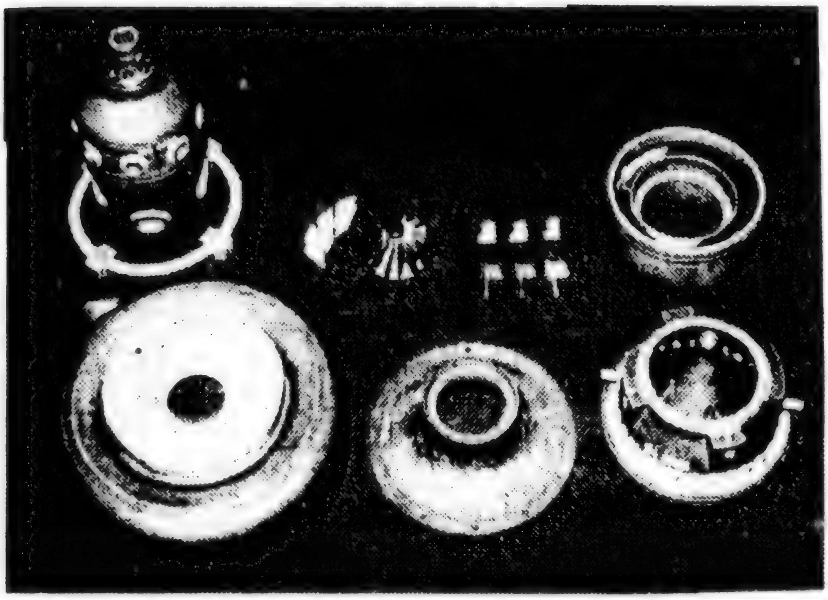

第3図 CGT303の主なセラミック部品
Fig.3

Figure 3. Main Ceramic Parts for the CGT303

Trends in Cogeneration

94FE0480C Tokyo ENERGY in Japanese
1 Feb 94 pp 35-38

[Article by Tatsuo Toge, Director of the Japan Cogeneration Society. Third of eight articles in the special issue on "City Gas Companies Putting Efforts Into Cogeneration"]

[Text]

Effective Utilization of Energy Through "Serial" Operation

Energy is extremely important for Japan, which depends on imports of most of its primary energy, in order to sustain and develop economic activity and social life. The amount of energy consumed by the Japanese industrial sector has been kept at the level attained during the first oil shock of 1973, due to the introduction of energy conserving technologies in response to the oil crisis, but energy consumption in the public and transportation sectors has greatly increased due to factors such as changes in lifestyle and advances in communications. Although future economic growth and changes in the industrial structure are unclear because of the recent sluggish market, Japan's energy consumption is expected to increase over the long term.

Therefore, resource-poor Japan must promote even more energy conservation and efficient utilization of its energy, to say nothing of ensuring its energy supply. In addition, we must make efforts to control CO_2 emissions with policies for protecting the global environment, such as global warming policies; this requires controlling the aforementioned energy consumption through conservation.

The actual state of Japan's energy use is that petroleum, coal, LNG (liquified natural gas), and nuclear fuel are imported, and all are burned so that the high temperature heat is utilized. Part of this heat energy is changed into power for running generators and automobiles, and is utilized as "electrical energy" and "mechanical energy"; the remainder is kept in the form of heat and is used as "heat energy" for industrial and public use. This is the usual scenario: when power generation is the only goal, it is generated by driving a heat engine by burning fuel, but the waste heat is discarded; on the other hand, when heat is desired a boiler is run—both separate, or "parallel" to one another. Consequently, the promotion of energy conservation is carried out separately—electricity and heat. However, it is vital that we consider electricity and heat together in order to achieve greater conservation of energy.

If the high temperature energy obtained from burning fuel is first converted as efficiently as possible to energy that is easily utilized for motive power and electricity, and once the temperature drops, the emitted waste heat is then utilized for hot water and for heating and cooling (that is, a "serial" operation), it would be extremely helpful in terms of effective energy use.

Cogeneration is based on this way of thinking. An example of a system in which energy is utilized very efficiently is shown in Figure 1, where gas turbines, gas engines, and diesel engines are supplied with gas or kerosene and manufacture motive power or electricity while steam and hot or cold water are simultaneously

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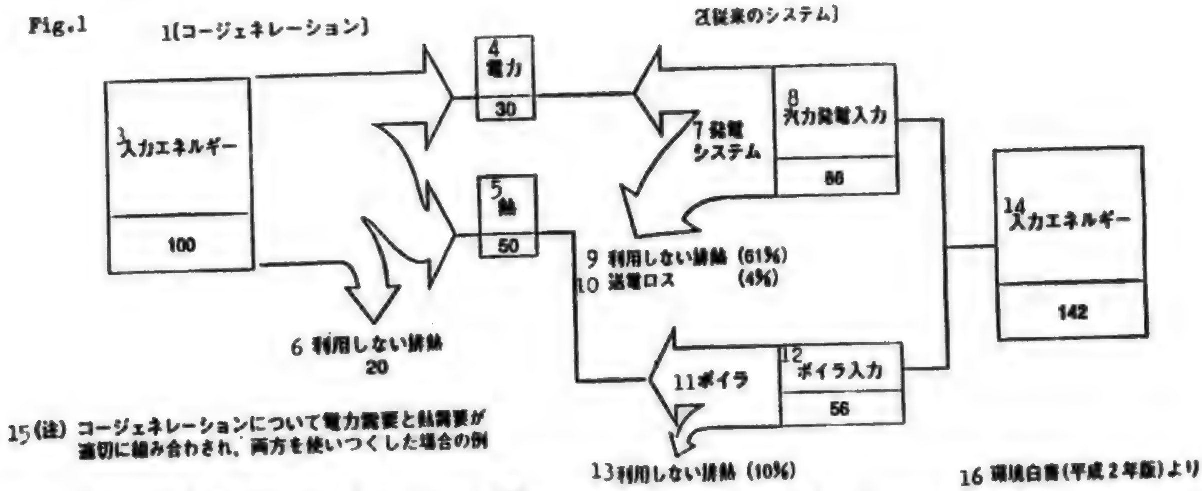

Figure 1. A Comparison of the Energy Efficiency of Cogeneration and the Currently Existing System

Key: 1. Cogeneration 2. Current system 3. Energy input 4. Electricity 5. Heat 6. Waste heat not utilized 7. Power generation system 8. Steam power generation input 9. Waste heat not utilized 10. Power transmission loss 11. Boiler 12. Boiler input 13. Waste heat not utilized 14. Energy input 15. Note: This example shows cogeneration where electrical and heat demand are favorably combined and both electricity and heat are used up. 16. From White Paper on the Environment (1990)

obtained by using the waste heat. The currently existing system, in which inputs of primary energy for creating the electricity and heat needed for final consumption are separated, is shown on the right, while the cogeneration method is shown on the left.

Current State of Cogeneration Utilization

Current Conditions for Cogeneration

The Japan Cogeneration Society has carried out a survey on the existing conditions for introducing cogeneration, by obtaining the cooperation of each member company. Table 1 shows the current conditions with gas turbines, gas engines, and diesel engines combined, as of the end of March 1993. Facilities for public use numbered 868, with generation capacity being 409,000kW, and there were 664 industrial facilities with a generation capacity of 2,107,000kW, for a total of 1,532 establishments with a generation capacity of 2,516,000kW. This is approximately 1.4 percent of the total capacity of the 10 electrical utilities, which is 180,980,000kW.

Table 1. Current State of Cogeneration (as of March 1993)

	Number of Establishments	Generation Capacity (kW)	Generation Capacity per Establishment (kW/Establishment)
For Public Use	868	409,313	472
For Industrial Use	664	2,106,580	3,173
Total	1532	2,515,893	1,642

Figure 2 shows the total record of cogeneration introduction by fiscal year and by the number of establishments and generation capacity, with a sudden increase in the period 1985 to 1990. This was made possible through a system of electrical contracts for power from independent power generation sources and the establishment of guidelines for system linkages in 1986, the application of a financial investment system and expansion of the range of specially designated supplies targeted for investment in 1987, and relaxing inspections of small gas turbines and enabling outside commissioning of electrical chief technicians in 1988. The continued easing and provision of legislation in 1992, which established terms and fees for selling surplus power, is also thought to be a factor. The figure shows estimates as of September 1993.

Current State By Prime Mover

Gas turbines, gas engines, and diesel engines are the prime movers used for cogeneration, and are utilized according to their respective capabilities. Gas turbines are used in mid-sized systems of 500 to 100,000kW; the generation efficiency is only 20 to 30 percent, but these are appropriate for areas with a high heat demand because the waste heat recovery rate is high. Diesel

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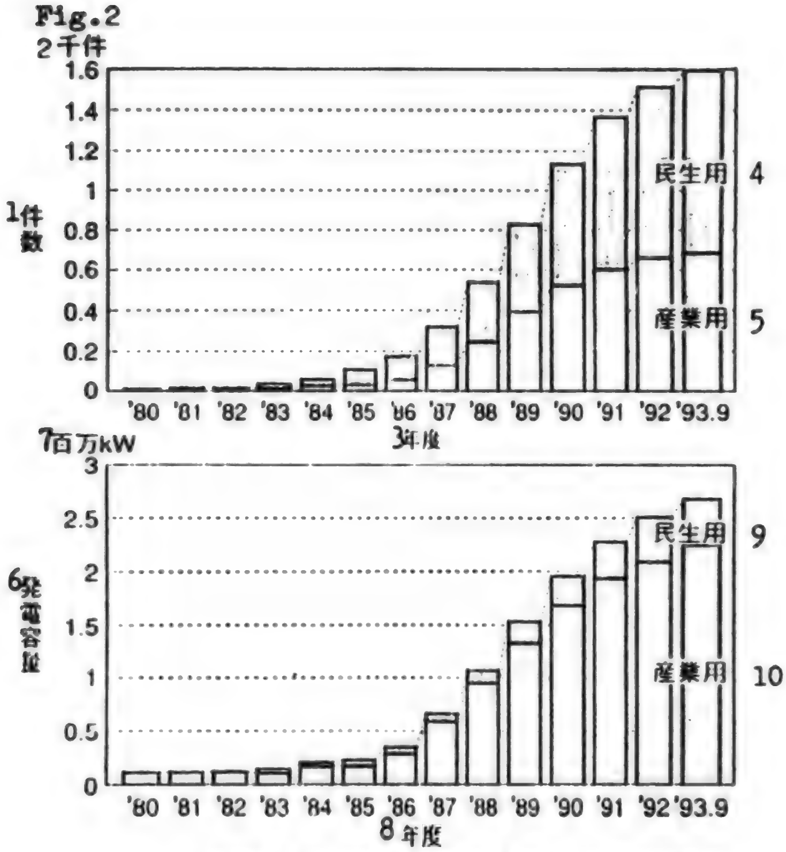

Figure 2. Change in Current State of Cogeneration

Key: 1. Number of establishments 2. Thousands of establishments 3. Fiscal year 4. For public use 5. For industrial use 6. Generation capacity 7. Millions of kW 8. Fiscal year 9. For public use 10. For industrial use

engines are used in small- and mid-sized systems of 50 to 3,000kW, and have a higher generation efficiency of 35 to 45 percent, but because the waste heat recovery rate is low, these are appropriate for areas where electrical demand is high. Gas engines are somewhere in between the two, with a power generation efficiency of 30 to 38 percent. Table 2 shows the current conditions by prime mover. The number of establishments differs somewhat from Table 1, due to the existence of different engines at the same facility.

Table 2. Current State of Cogeneration by Type of Motor (as of March 1993)

		Number of Establishments	Generation Capacity (kW)	Generation Capacity per Establishment (kW/Establishment)
Gas Turbines	For public use	20	46,120	2,306
	For industrial use	141	1,027,240	7,285
	Total	161	1,073,360	6,667
Gas Engines	For public use	372	113,317	305
	For industrial use	158	82,730	524
	Total	530	196,047	370
Diesel Engines	For public use	479	249,876	522
	For industrial use	366	996,610	2,723
	Total	845	1,246,486	1,475

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Current State of Cogeneration for Public Use

Table 3 shows the number of public establishments and generation capacity by type of building.

Table 3. Current State of Cogeneration for Public Use, by Type of Facility (as of March 1993)

Building Use	Offices	Hotels	Sports Facilities	Gas Stations	Stores	Training & Health Centers	Research Facilities	Computing Facilities	Hospitals	Schools	Other	Total
Number of Establishments	150	172	113	80	106	85	31	4	60	22	45	868
Generation Capacity	51,228	91,736	57,786	4,905	67,927	32,049	8,629	7,916	25,065	13,993	48,079	409,313
Generation Capacity per Establishment (kW/Establishment)	342	533	511	61	641	377	278	1,979	418	636	1,068	472

There are 172 hotels, 150 office buildings, 113 sports facilities, and 106 stores; these account for approximately 62 percent of the total. Hotels account for about 92,000kW of the total generation capacity, stores account for 68,000kW, sports facilities account for 58,000kW and offices account for 51,000kW. All have a standard heat demand in the form of steam and hot and cold water, and the long hours of operation for each of these is a distinguishing feature. Computing centers, while fewer in number, have the greatest capacity per establishment; "Other" is also quite large because it includes regional air conditioning.

Current State of Cogeneration for Industrial Use

Table 4 shows the current situation by type of industry.

Table 4. Current State of Cogeneration for Industrial Use, by Type of Industry (as of March 1993)

Type of Industry	Breweries	Bakeries	Other Foods	Total Foods	Textiles & Pulp	Pharmaceuticals	Other Chemicals	Total	Pharmaceuticals & Chemicals	Steel & Metals	Electric Machinery	Machinery
Number of Establishments	14	12	80	106	55	43	19	113	132	50	46	67
Generation Capacity (kW)	18,105	9,838	81,934	109,877	144,025	152,734	47,100	580,669	627,769	283,743	68,460	115,104
Generation Capacity per Establishment (kW/establishment)	1,293	820	1,024	1,037	2,619	3,552	2,479	5,139	4,756	5,675	1,488	1,718
Type of Industry	Gas	Petroleum	Other Energy	Total Energy	Water & Sewers	Wood & Composite Board	Glass & Soda	Cement & Other	Total Ceramics	Printing	Services	Mining
Number of Establishments	13	24	2	39	18	15	10	14	24	13	10	7
Generation Capacity (kW)	7,124	308,792	26,350	342,266	12,095	25,620	66,880	61,010	127,890	20,018	6,660	30,904

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Table 4. Current State of Cogeneration for Industrial Use, by Type of Industry (as of March 1993) (Continued)

Type of Industry	Breweries	Bakeries	Other Foods	Total Foods	Textiles & Pulp	Pharmaceuticals	Other Chemicals	Total	Pharmaceuticals & Chemicals	Steel & Metals	Electric Machinery	Machinery
Generation Capacity per Establishment (kW/establishment)	548	12,866	13,175	8,776	672	1,708	6,688	4,358	5,329	1,540	666	4,415
Type of Industry	Other	Total										
Number of Establishments	39	664										
Generation Capacity (kW)	39,415	2,106,580										
Generation Capacity per Establishment (kW/establishment)	1,011	3,173										

Chemicals account for the greatest number of establishments with 132 facilities, followed by food with 106, and machinery with 67 facilities, and then textiles, metals, electric machinery, and paper and pulp, each with about 50 establishments. These types of industries utilize large amounts of steam and hot water in the production process, with a large number of operating hours annually.

Moreover, chemicals also have the largest generation capacity at nearly 628,000kW, followed by energy with 342,000kW, and metals with 284,000kW; energy has the largest capacity per establishment with 8,800kW, and the mining and ceramics industry, including glass and cement which also h ve large capacities per establishment. Food and electric machinery are smaller in scale, with 1,000 to 1,490kW per establishment.

Future Issues

At the present time, when we must consider energy problems and global environmental policies together, the use of cogeneration is getting a closer look. Nationally, MITI's Pro-Environment Energy Community, the Ministry of Construction's Environmental Housing Developments, and Ministry of Home Affair's Super Refuse Power Generation concept have incorporated the cogeneration idea.

In order to promote the spread of cogeneration even more, we must continue to promote the technological advances achieved up to this point, ease regulations, and formulate a system. Technological development includes techniques for raising efficiency, improving reliability, establishing units and packaging, and reducing pollution and costs.

In order to raise efficiency, applications of heat-resistant ceramic materials are being studied, as are ways to increase turbine intake temperature. Application of a space-conserving high efficiency system developed at A‿T90 is expected.

Improving reliability includes developing a management method that efficiently and effectively carries out the running and maintenance of a facility. Technical development themes include making equipment more compact in order to reduce the area needed and simplifying equipment, and lowering NO_x emissions.

In addition, development is continuing on new cogeneration technologies such as fuel cells and a hybrid solar heat/sunlight system.

In terms of a system, even more study is expected on the items from an Executive Council report on the results of an administrative inspection of energy, in order to promote decentralization of power sources. This includes technological requirements related to the range of specially designated supplies, formal approval, licensing requirements, a system for purchasing surplus electricity, and system linkages, as well as cogeneration and making emergency generators public.

Furthermore, active technological cooperation, such as transferring our accumulated cogeneration technology to developing countries where power supplies are threatened by increases in energy consumption, will most likely contribute to solving global environmental problems.

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Tokyo Gas Working Towards Cogeneration

94FE0480D Tokyo ENERGY in Japanese
1 Feb 94 pp 39-43

[Article by Masao Ogura, Head of the Total Energy System Division, Tokyo Gas Company, Ltd. Fourth of eight articles in the special issue on "City Gas Companies Putting Efforts Into Cogeneration"]

[Text]

From Alternative to Energy Mainstay

Tokyo Gas Company anticipated the environmental crisis, and in 1969, it was the first company in Japan to import natural gas. Compared to oil and coal, natural gas is a good quality fuel that does not contain sulfur and emits only a small amount of nitrogen oxides. Moreover, the quantity of carbon dioxide (a greenhouse gas) emitted per unit of heat is 67 percent that of coal and 85 percent that of oil.

This clean-burning natural gas has, up to now, been positioned as an "alternative energy" that supplements oil, but in June 1992 natural gas was designated a "mainstay energy" source.

At the same time, Tokyo Gas introduced natural gas, the company was also putting efforts into developing "utilization technologies" for effective use of natural gas, a finite fossil fuel. One of these was a cogeneration system, which was incorporated into the company's head office building in 1984, and was Japan's first cogeneration attempt in a public facility. After that, the introduction of cogeneration for public and industrial use progressed, so that by March 1993 there were 191 cogeneration facilities within Tokyo Gas's supply region, with a capacity of 267,000kW.

This article describes the company's efforts towards promoting cogeneration, which is key for effective utilization of natural gas.

Cogeneration and Natural Gas

The "Subcommittee for Study of Fundamental Questions on Gas," (Chair, Professor Uekusa of Tokyo University) established under MITI's National Energy Council Municipal Energy Sub-Committee, published an interim report in May 1992. This report placed natural gas, which up to that point was considered an alternative to petroleum, into a position of being an energy mainstay, based on environmental issues, the increased demand for electricity, and strengthening energy security. It then expressed the need to popularize cogeneration and gas cooling in order to promote the use of natural gas.

Verification Tests

Cogeneration first attracted notice in Japan at the end of 1975, although there were very few operating examples. At that time the old main office building became too small and a new building was planned; the plan incorporated an advanced energy system which was also being tested. At that time, system linkages were not approved, and so there were various problems associated with introducing linkages, but actual implementation of cogeneration was successful. This system is not limited to cogeneration, but is an "entire street" system that combines the heat supply for the whole area around the building, and is known as a CES (Community Energy System). The plan attracted a great deal of attention as Japan's first real cogeneration for public use.

The system was expanded when the building was later enlarged, and is operating as shown in Figure 2; it conserves energy as well as helps the environment.

Following the CES project, Tokyo Gas introduced a number of systems as a way to test the energy conservation capabilities of cogeneration in response to various kinds of demand. The types of industries using these systems include offices, restaurants, banquet halls, regional air conditioning, and sports clubs.

Support Software

Cogeneration is an energy-saving system that demonstrates its true value when electricity and waste heat are used in balance; it is very different from current systems in which only heat or only electricity is utilized. Consequently, an appropriate plan is required before introducing a cogeneration system. For that reason, a "simulation" is generally carried out, and the economy, energy savings, and environmental aspects need to be considered when deciding on the optimal system.

To make the system really work, it is necessary to determine a balance between heat and electricity supply and demand every hour, which requires a computer. At present, software is being developed for this purpose in a number of quarters. However, the TESP (Total Energy Simulation Program) developed by Tokyo Gas, which is based on the logic of the National Institute for Research Advancement (NIRA), is easy to use and has been upgraded several times. In addition to Tokyo Gas, other leading gas enterprises utilize the program, which can provide services for demand outside the National Capital Region. Figure 3 shows an example of TESP output.

Technological Development

Cogeneration has a short history in Japan, and in order to popularize it, we need a great deal of technological development in terms of raising efficiency, reducing costs through efforts such as space conservation and environmental protection measures. In addition, efforts are continuing in all quarters on environmentally safe, high efficiency fuel cells as the next generation of cogeneration systems.

Table 1 is a summary of current technological developments.

Recently, there has been an attempt to optimize a municipal energy system (Pro-Environment Energy

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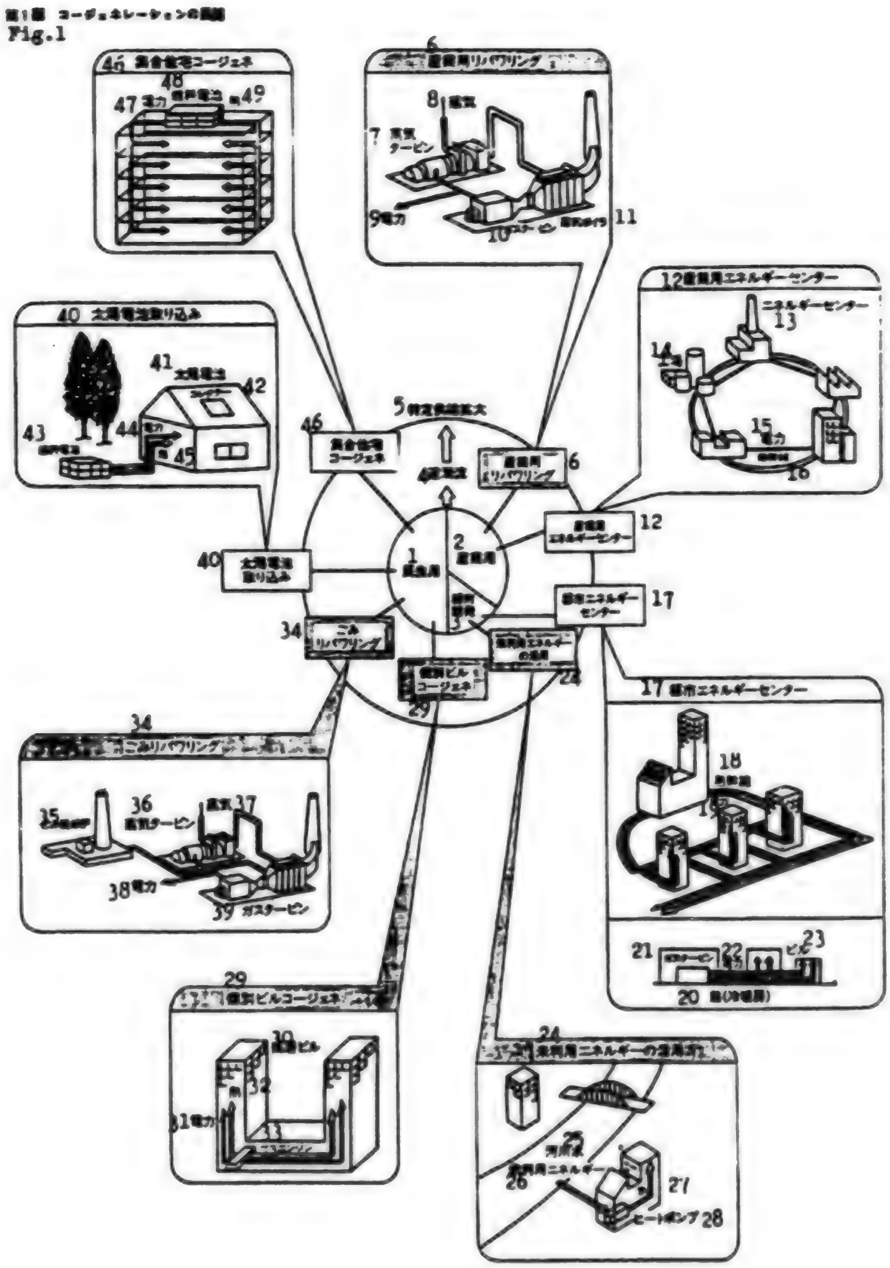

Figure 1. The Development of Cogeneration

Key: 1. Public use 2. Industrial use 3. Municipal development 4. Counterflow 5. Expanding specified supply 6. Repowering for industrial use 7. Steam turbine 8. Steam 9. Electricity 10. Gas turbine 11. Steam boiler 12. Energy center for industrial use 13. Energy center 14. Factory 15. Electricity 16. Heat line 17. Municipal energy center 18. Heat line 19. Electricity 20. Heat (air conditioning) 21. Gas turbine 22. Electricity 23. Building 24. Putting unused energy to use 25. River water 26. Unused energy 27. Heat 28. Heat pump 29. Cogeneration for individual buildings 30. Skyscraper 31. Electricity 32. Heat 33. Gas engine 34. Refuse repowering 35. Incinerator 36. Steam turbine 37. Steam 38. Electricity 39. Gas turbine 40. Utilization of photovoltaic cells 41. Photovoltaic cell 42. Collector 43. Fuel cell 44. Electricity 45. Heat 46. Multiple dwelling cogeneration 47. Electricity 48. Fuel cell 49. Heat

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第2図 CES概念図
Fig.2

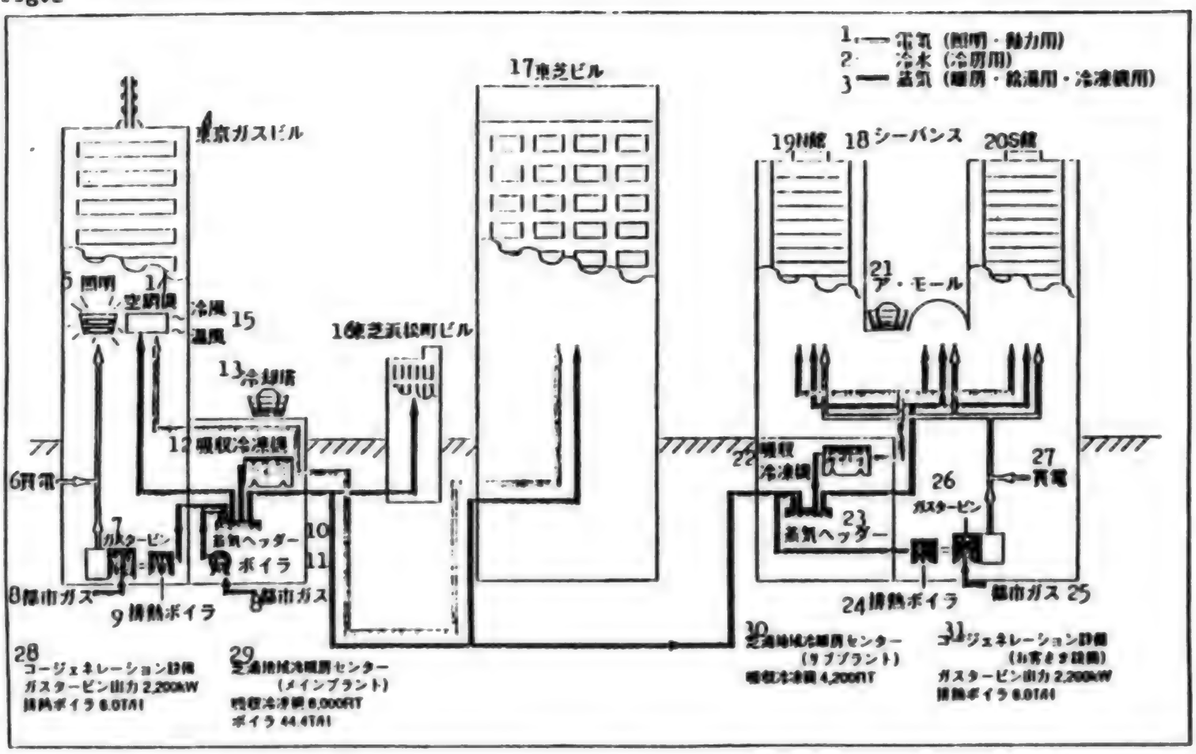

Figure 2. Conceptual Diagram of CES

Key: 1. Electricity (lighting and power) 2. Cooled water (air conditioning) 3. Steam (heating, hot water, and refrigeration) 4. Tokyo Gas building 5. Lighting 6. Purchased power 7. Gas turbine 8. City gas 9. Waste heat boiler 10. Steam header 11. Boiler 12. Absorption refrigerator 13. Cooling tower 14. Air conditioner 15. Hot and cold air 16. Toshiba Hamamatsu- cho building 17. Toshiba building 18. *Shiibansu* [building name] 19. N building 20. S building 21. Amoru [building name] 22. Absorption refrigerator 23. Steam header 24. Waste heat boiler 25. City gas 26. Gas turbine 27. Purchased power 28. Cogeneration facility: gas turbine output 2,200kW, waste heat boiler 6.0T/H 29. Toshiba regional air conditioning center (main plant): absorption refrigerator 6,000RT, boiler 44.4T/H 30. Toshiba regional air conditioning center (sub-plant): absorption refrigerator 4,200RT 31. Cogeneration facility (customer facility): Gas turbine output 2,200kW, waste heat boiler 6.0T/H

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第3図 TESPの出力例
Fig.3

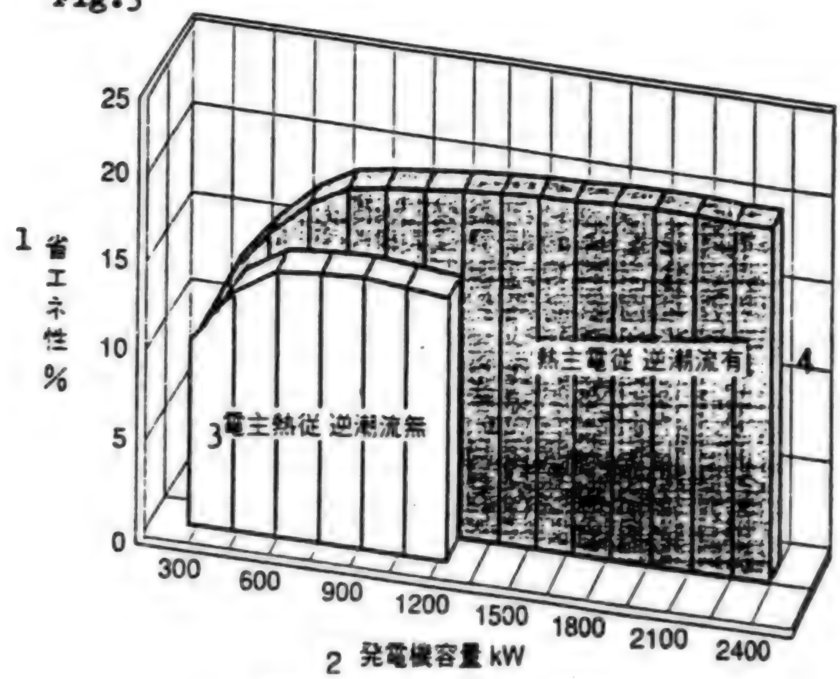

Figure 3. Example of TESP Output

Key: 1. Percent conserved 2. Generator capacity 3. Primarily electricity followed by heat; no counterflow 4. Primarily heat followed by electricity; with counterflow

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Table 1
第1表 コージェネレーション技術開発一覧
(ガス3社共同開発テーマを含む)

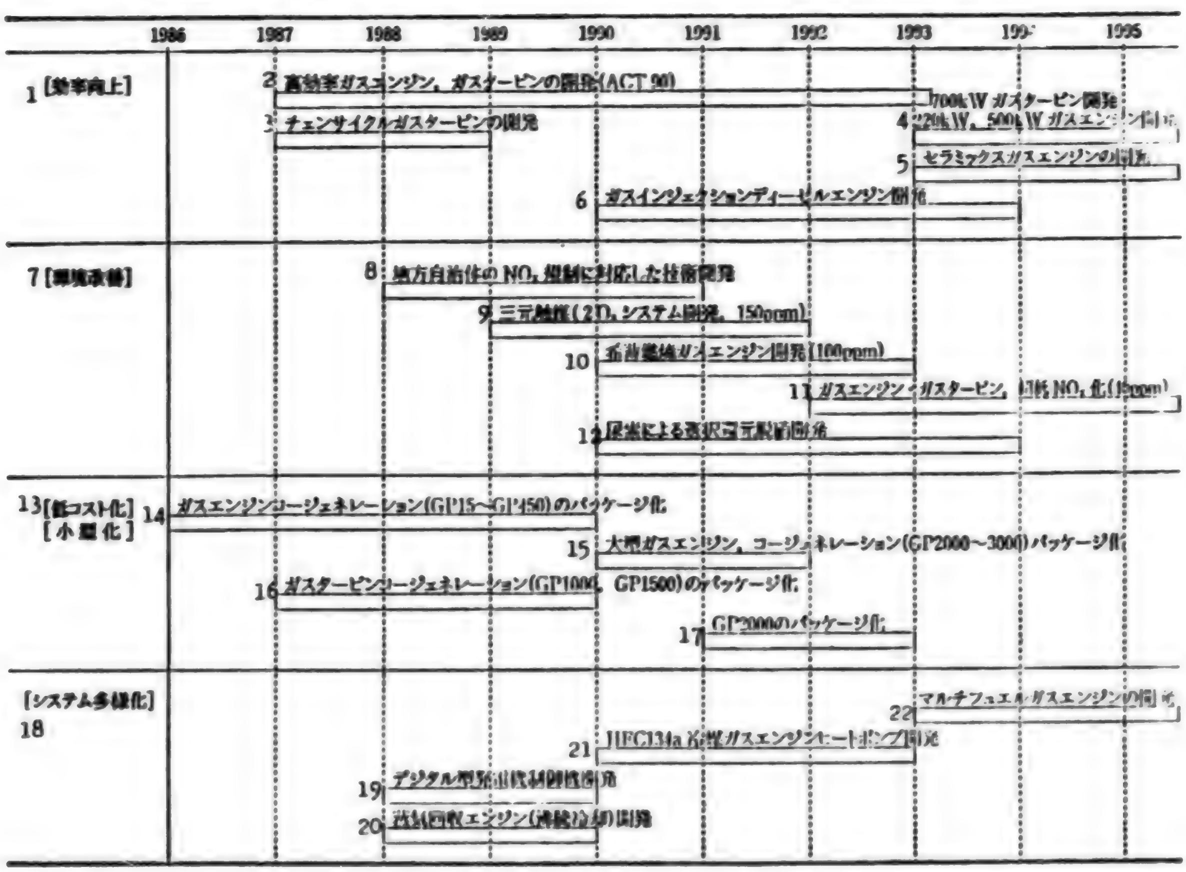

Table 1. Summary of Technological Developments in Cogeneration (Including themes researched jointly by the three gas companies)

Key: 1. Raising efficiency 2. High-efficiency gas engines and gas turbines developed (ACT90) 3. Chain cycle gas turbine developed 4. 700kW gas turbine and 220kW, 500kW gas engines developed 5. Ceramic gas engine developed 6. Gas injection diesel engine developed 7. Improving the environment 8. Technology developed in response to regional NO_x legislation 9. Ternary catalyst ($2O_2$ system, 150ppm) developed 10. Lean burn gas engine (100ppm) developed 11. Ultra-low NO_x gas engine and gas turbine (40ppm) 12. Selective reduction denitration by using urea 13. Lowering costs, reducing size 14. Packaging of gas engine cogeneration (GP15-GP450) 15. Packaging large gas engine cogeneration (GP2000-3000) 16. Packaging gas turbine cogeneration (GP1000, GP1500) 17. Packaging GP2000 18. System diversification 19. Digital generator controller developed 20. Steam collection engine (boiling and cooling) developed 21. HFC134a Cool medium gas engine heat pump developed 22. Multi-fuel gas engine developed

Community), and development has begun on a Super Refuse Power Generation project which combines gas turbines with the waste heat from an incinerator; both projects put the principles of cogeneration (cascade utilization of heat) into practice. Efforts are continuing in developing those systems.

System Operation

Cogeneration is usually engineered on a small scale, but in order to safely run a cogenerator which includes both electrical and heat work, a coherent organization responsible for carrying out planning, design, execution, and maintenance is desirable. In addition to accepting orders for a 300kW gas engine cogeneration system, Tokyo Gas also provides an integrated system for placing orders, from engineering to maintenance, based on customer demand.

This 300kW cogeneration system is called "Genemaru"; the gas engine itself is a lean burn engine developed by the three gas companies with an efficiency of 36.2 percent (LHV = low heat volume) and NO_x at or below 200ppm (O_2 calculated as 0 percent).

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第4図　コージェネレーション遠隔運転・監視システム

Fig.4

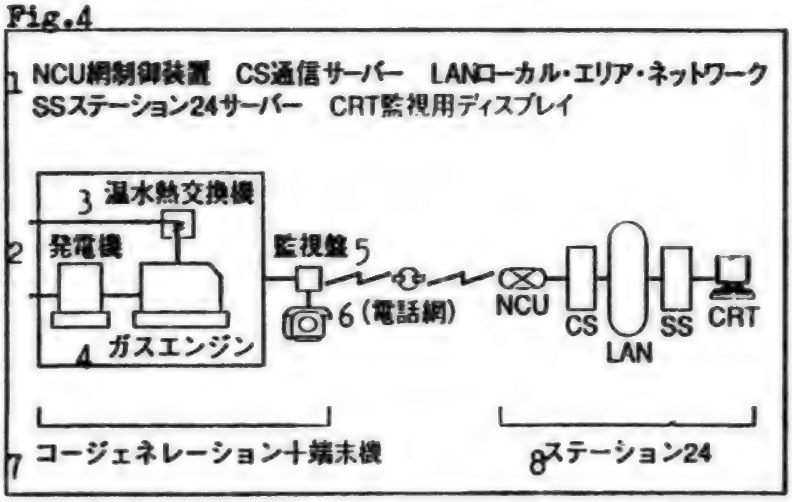

Figure 4. Remote Operation and Observation System for Cogeneration

Key: 1. NCU = network control unit, CS = communications server, LAN = local area network, SS = station 24 hour server, CRT = display for observation 2. Generator 3. Hot water heat exchanger 4. Gas engine 5. Observation board 6. Telephone network 7. Cogeneration + terminal 8. Station 24

Operation Maintenance

A reliable maintenance system is necessary in order to safely operate a cogeneration system. Tokyo Gas has for some time offered an "intelligent service" called "Station 24" which protects the consumer with a 24-hour home security system; this system can also provide a means of remote operation and observation for cogeneration as well. This system is shown in Figure 4.

Furthermore, a system that diagnoses cogeneration failure using the latest artificial intelligence technology has been developed, and is currently undergoing field tests. In the future, reliability of cogeneration systems can be improved if the reliability of failure detection and failure prediction is improved.

A 10 Percent Increase by 2000

In order to effectively utilize natural gas, which is a clean energy and a mainstay energy source, Tokyo Gas proclaimed 1992 to be the "Year of Conservation" and the "Year of the Environment." The challenge for conservation was "raising the level of efficiency 10 percent from 1990 to 2000," and the challenge for the environment was "stabilizing NO_x emissions to 1990 levels by 2010." Cogeneration is a large part of achieving these goals. The success of these proclamations has been due to the expansion of cogeneration, which we hope will contribute to Japan's conservation and environmental efforts.

Osaka Gas Working Towards Cogeneration

94FE0480E Tokyo ENERGY in Japanese 1 Feb 94 pp 44-47

[Article by Takashi Nabari, Business Development Team Manager, Osaka Gas Company's Industrial Energy Business Division. Fifth of eight articles in the special issue on "City Gas Companies Putting Efforts Into Cogeneration"]

[Text] Osaka Gas is making an effort to popularize cogeneration as one of the supports for increasing gas demand. As of September 1993, nearly 10 years after cogeneration was first introduced, our customer base for cogeneration is nearly 230 establishments with a generation capacity of about 500,000kW; of these, about 110 facilities with a 450,000kW capacity have been built and are operating for industrial use.

This article examines in more concrete terms our "cogeneration system that gives the customer an advantage," as experienced through business activity in the industrial market.

Prerequisites for an Advantageous Cogeneration System

Discussions of cogeneration systems repeatedly focus on discussions of "raising the overall efficiency within cogeneration battery units." However, "efficiency" means "static state efficiency," and cannot be considered adequate as an indicator of true worth for a customer (a system user). "Real advantages" for a user must mean a "cogeneration system giving value while in an operating state, that is, while actively engaging in production."

Of course, the level of power generation efficiency and overall efficiency is a vital part of increasing the advantages of having the system, and "improving the overall efficiency within the unit" is primarily based on the performance of the constituent machinery such as engines and waste heat boilers. Future research and development by each manufacturer is greatly anticipated.

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Besides "improving overall efficiency within the unit" as a way to increase the "advantages" of the system even more, the various factors below must be examined:

(1) Constructing a system that can operate as long as possible at full capacity: Even systems having good overall efficiency experience a reduction in value if the rate of operation is low, and short-term amortization of much of the investment in equipment becomes impossible. The point here is understanding a factory's use of utilities, such as electricity, steam, and cooling water. Because utility use varies greatly by season or time of day, operating conditions during the production process must be studied and analyzed in detail, and a cogeneration system must be constructed based on the data. If a grasp of the situation is neglected, the result will be a partial burden on operations.

(2) Constructing a system in which the electricity, steam, and hot and cold water can be used as much as possible in production processes giving a high added value: This is important in terms of expanding the "advantages" of the system. The shaft power of internal combustion engines, for which there is no high-potential substitute, should be used for power and electricity, and hot water, which has the lowest potential energy and is the most difficult to use, should somehow be utilized.

(3) Improving reliability by perfecting pre-maintenance in order to prevent tripping, and reducing maintenance costs with regular inspections: If tripping occurs, the number of "advantages" drops. Osaka Gas is aiming for improved system reliability, and is putting all its efforts in reducing problems, in cooperation with customers and manufacturers. Increasing system value by reducing maintenance costs is also considered to be an important component.

The factors described above for increasing the number of "advantages" are explained below using concrete examples.

Examples of Systems Having Advantages

A cogeneration system for a *sake* brewery, in which electricity and utility use varies greatly between day and night

The pattern of the electrical load before cogeneration was installed was as shown in Figure 1.

The night load was approximately one-fifth of the daytime load. The fact that there was a load for cold water, refrigeration, and hot water for heating during the day, but no hot and cold water load at night, is also clear. The following points were noted for constructing a cogeneration system:

1. Day and night operation could be carried out with the entire load.
2. All of the waste heat could be utilized.
3. There could be a back-up within the system.

第1図 ガスエンジン冷凍機+氷蓄熱システム

Fig. 1

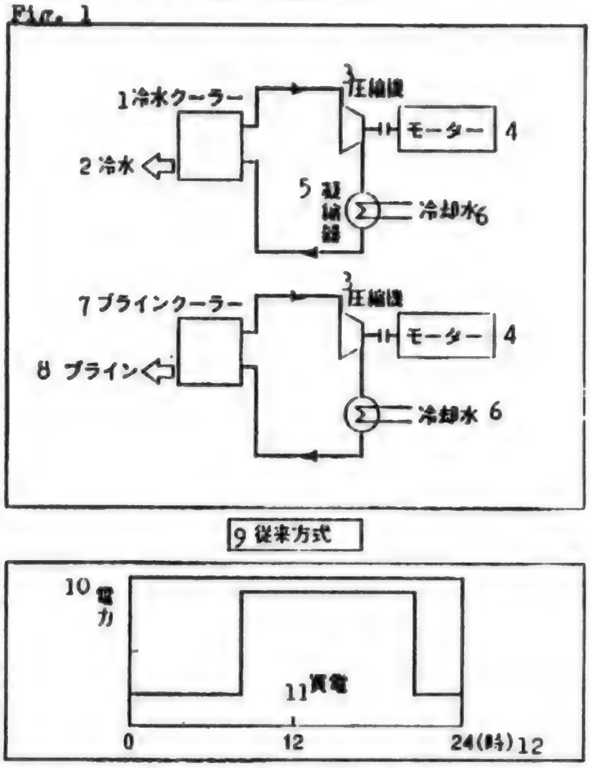

Figure 1. A Gas Engine Refrigerator and Ice Regenerative System

Key: 1. Water cooler 2. Cold water 3. Compressor 4. Motor 5. Condenser 6. Cooling water 7. Brine cooler 8. Brine 9. Existing system 10. Electricity 11. Purchased power 12. Hours

4. Economies of scale would be pursued.

With attention given to the above points, a system was constructed as shown in Figure 2.

The system features the following:

1. The gas engine, generator, and compressor are combined in tandem, and the gas engine load and purchased electricity load are standardized for day and night.
2. The cooling load due to cold storage occurs through the night hours.
3. The peak cut of electricity from the gas engine generator is planned for daytime hours, and the absorption refrigerator is run with waste heat and supplies cold water.
4. At night, the day's cooling load is stored by means of a gas engine compressor, and waste heat is stored as hot water for use during the day.
5. When the gas engine is shut down (such as for maintenance), the generator is used as a motor, and can be operated as a cooling system.

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第2図 ガスエンジン冷凍機+氷蓄熱システム
Fig. 2

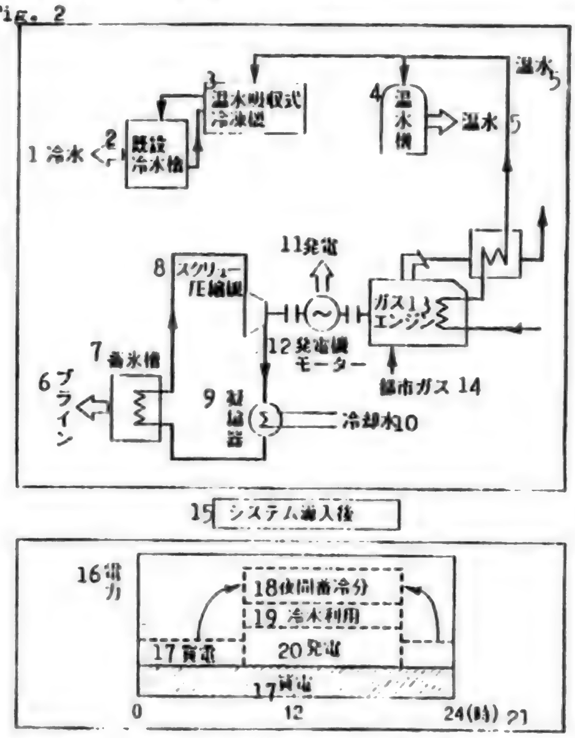

Figure 2. A Gas Engine Refrigerator and Ice Regenerative System

Key: 1. Cold water 2. Existing cold water tank 3. Hot water absorption refrigerator 4. Hot water tank 5. Hot water 6. Brine 7. Cold storage tank 8. Screw compressor 9. Condenser 10. Cooling water 11. Power generation 12. Generator motor 13. Gas engine 14. Municipal gas 15. After the new system was introduced 16. Electricity 17. Purchased power 18. Night cold storage 19. Cold water use 20. Power generation 21. Hours

The bottom part of Figure 2 shows the electrical power pattern after cogeneration was installed. By installing a generator to provide one-fifth of the power contracted before cogeneration was installed, contracted power was cut in half.

A cogeneration system for a beer factory, in which the change in the steam load is quite large

Although the beer factory's electrical load was stable and the heat demand quite large, the change in steam load was very pronounced. Therefore, waste heat could not be used up if a gas turbine was selected from the electrical load. But if one was selected from the steam load, capacity decreased, which would not be worthwhile. Gas turbine cogeneration installed together with an accumulator was proposed as a way to solve this problem.

Figure 3 shows the change in the actual steam load and the change in the steam load exiting the boiler when an accumulator is installed.

As shown in the figure, the accumulator absorbs the sudden changes in the steam load, and as viewed from the boiler, the steam load is stable. The right part of the figure shows the cogeneration system flow. The system features the following:

1. By installing an accumulator, gas turbine cogeneration can be smoothly operated.

2. The boiler's sudden load change is absorbed, and boiler efficiency is raised; steam quality improves as well.

3. The capacity of the waste heat boiler is seemingly increased by using an accumulator, and the number of boilers regularly operating can be reduced.

A cogeneration system for a foundry that stabilizes product and molding quality and reduces the amount of foundry coke

In order to achieve the above objectives, it is necessary to dehumidify the air for ventilation. In concrete terms:

1. Stabilizing quality: the coke, pig iron, and slag mixing ratio is uniform because it is ventilated at a prescribed level of humidity and temperature, which lowers the variability in quality and the percentage of defects. (Relatively hot water is produced.)

2. Coke can be reduced: By raising the melting temperature, the ratio of coke can be reduced by approximately 1-3 percent.

3. Melting velocity is increased: melting velocity can be raised without increasing the amount of coke or ventilation, even when humidity is high.

A cogeneration system was built that targets dehumidifying the air blown into the cupola furnace and works as described above. The system flow is shown in Figure 4.

The system features the following:

1. Engine capacity is determined depending on the amount of ventilation to the cupola.

2. The gas engine's waste hot water passes through the hot water absorption refrigerator to produce cold water, and is used for the first stage of dehumidification of the air for ventilation.

3. The gas engine's waste gas is used as a regenerative heat source for the dehumidifier.

4. When the power is shut down, the system can be used as an emergency generator for the cupola ventilator.

Constructing cogeneration systems having the "advantages" described above requires close cooperation with customers and manufacturers. In the future, we want to work towards popularizing "advantageous" cogeneration systems while securing the cooperation of customers and manufacturing firms.

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第3図 ガスタービン・アキュムレーターシステム
Fig.3

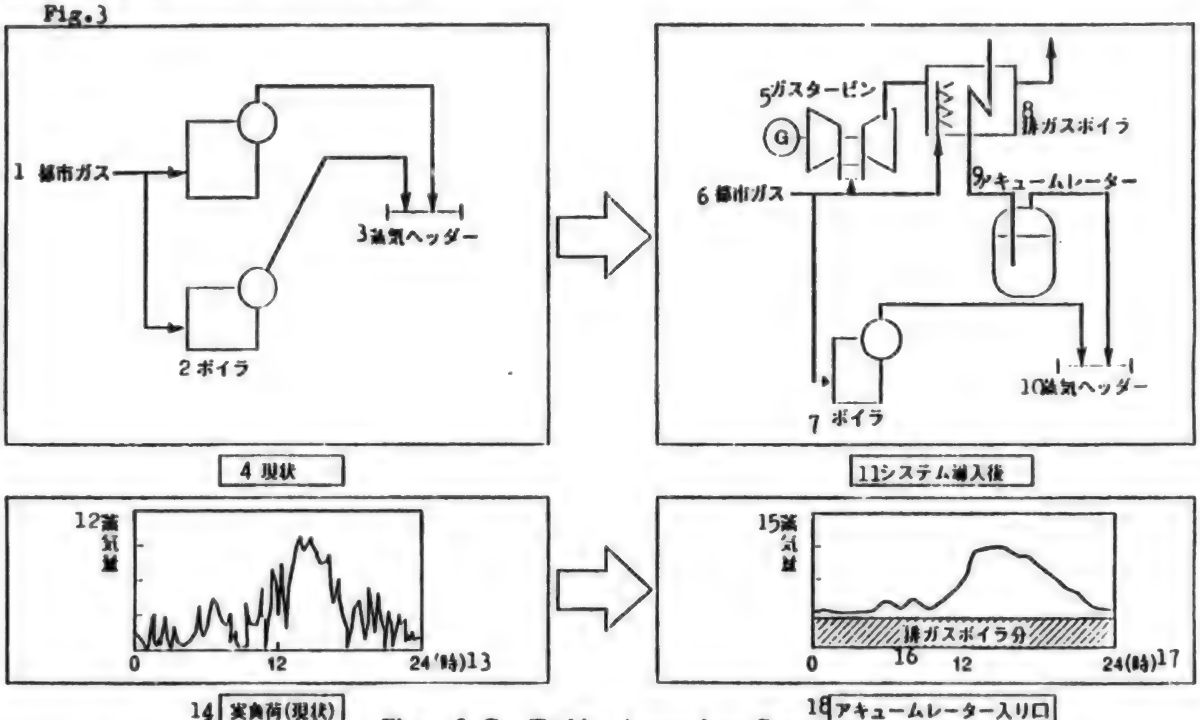

Figure 3. Gas Turbine Accumulator System

Key: 1. City gas 2. Boiler 3. Steam Header 4. Existing conditions 5. Gas turbine 6. City gas 7. Boiler 8. Waste gas boiler 9. Accumulator 10. Steam header 11. After the system is incorporated 12. Amount of steam 13. Hours 14. Actual load (existing system) 15. Amount of steam 16. Waste gas boiler 17. Hours 18. Accumulator intake

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第4図 システムフロー
Fig.4

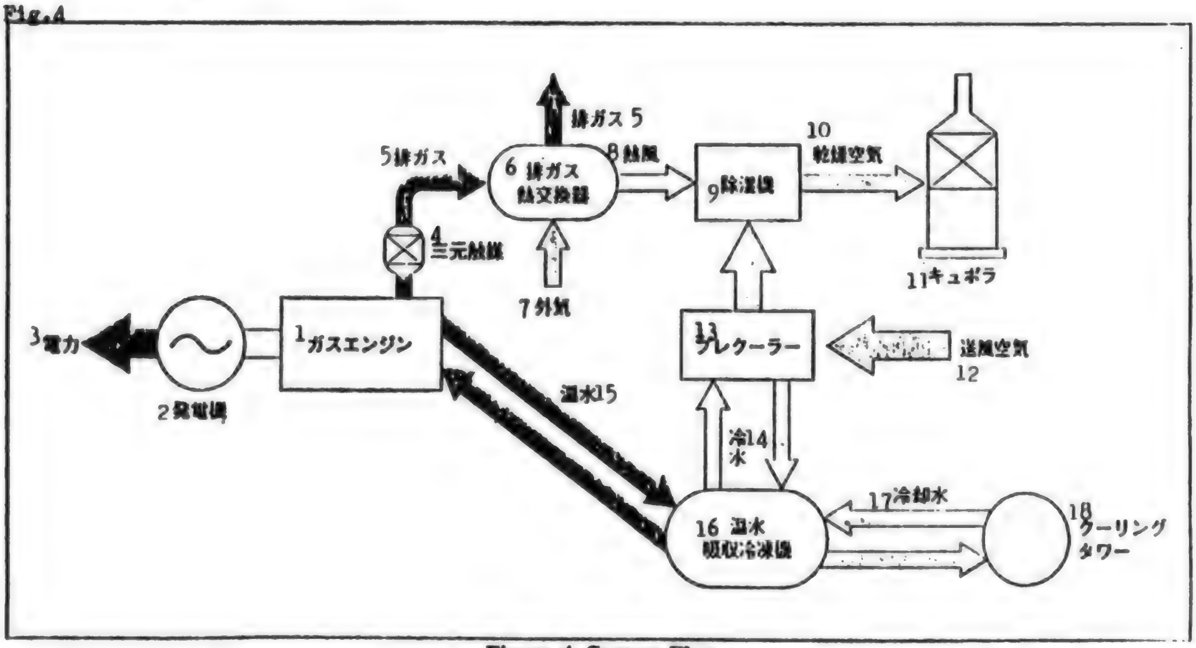

Figure 4. System Flow

Key: 1. Gas engine 2. Generator 3. Electricity 4. Ternary catalyst 5. Waste gas 6. Waste gas heat exchanger 7. Outside air 8. Heated air 9. Dehumidifier 10. Dry air 11. Cupola furnace 12. Air for ventilation 13. Precooler 14. Cold water 15. Hot water 16. Hot water absorption refrigerator 17. Cooling water 18. Cooling tower

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Efforts to Popularize Cogeneration at Toho Gas

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[Article by Iwao Hamamoto, Toho Gas Company's Municipal and Industrial Business Division Chief. Sixth of eight articles in the special issue on "City Gas Companies Putting Efforts Into Cogeneration"]

[Text]

Sudden Increase in Natural Gas Demand for Business

Toho Gas completed a natural gas conversion project at the end of May 1993. This was an opportunity to establish a natural gas-based production and supply system and to usher in the "age of natural gas."

This natural gas conversion operation began in June 1978; since then the sectors using city gas have rapidly expanded from home use to business and industrial use, due to the advantages of natural gas (clean, stable supply, etc.).

In terms of Japan's energy policies, natural gas was positioned as an alternative to oil, but it has now been designated as a mainstay energy source (June 1991 MITI National Energy Council's Subcommittee for Study of Fundamental Questions on Gas) for a number of reasons: as a response to energy security issues, environmental issues, and the increase in demand for electricity, and as a way to promote energy conservation. Expansion of cogeneration systems is desired along with expansion in gas air conditioners, as ways to increase natural gas use. This article describes the spread of cogeneration use in Toho Gas's supply region, and the company's efforts to popularize cogeneration.

Existing Conditions for Popularizing Cogeneration

In recent years, cogeneration has been in the spotlight as a means of reducing the amount of energy and addressing global environmental problems; there has been a rapid increase in measures to relax system-related regulations (Table 1) combined with measures for favorable public financing and tax breaks (Table 2).

Table 1. Measures to Relax Regulations on the System

Guidelines for decentralized power source system linkages	After MITI's Agency of Natural Resources and Energy communicated its "Requisite Guidelines for System Linkage Technologies" in August 1986, cogeneration through linkages with commercial power systems became popular as a more efficient system, and installation gradually progressed. Revisions were made for decentralized sources of power with new types of energy, such as power generation facilities with counterflow for in-house use and fuel cells.
In-house supply contracts for commercial use	"In-house supply contracts" were established in parallel with the above guidelines, as prerequisites for supply outside of the stipulated electrical supply. As a result, power shortages due to periodic inspection of cogeneration equipment or during times of trouble could be supplemented with commercial power (high voltage power and special high voltage power will be regulated from now on, and is provided to the business sector).
Expanding specially designated supplies	According to the August 1987 report of the "Subcommittee for Study of Cogeneration Issues," the electricity supplied by a building owner to relevant supply and demand within the building is permitted under Item 17 of the Electrical Industry Law, specially designated supplies. This allows the owner to supply power to the building tenants, which expands the range of applicable cogeneration systems.
Revising the chief electrical technician system	The regulations for enforcing the Electrical Industry Law were revised in May 1988, making non-designated electrical chief technicians eligible for contracts commissioned to the Electrical Safety Association. Establishments that can place commissions must have: 1) In-house power generation of less than 500kW, and 2) Demand of less than 1,000kW.
Rationalizing periodic inspections of small gas turbines	The legal inspection period for small gas turbines (less than 10,000kW) was extended to a maximum of five years and 1,000 starts, depending on annual operation time and design conditions; the time period was relaxed for independent inspection by system installers. Rationalization of pre-inspection is planned, through more emphasis on checks within the place of manufacture.
A system for purchasing surplus power	Instructions for purchasing surplus power from cogeneration sources rather than from the utilities were published in April 1992, and the unit cost of sale to the utilities was made public. Technical guidelines were summarized for cases in which counterflow is a technical requirement, and the unit cost of sale and other conditions varied somewhat from utility to utility, making cooperation with the utilities necessary when a project is planned.
Pro-Environment Energy Community Project	MITI published a "Promotion of Comprehensive Energy and Environmental Policies," and is starting a support structure for a "Pro-Environment Energy Community Project," which will grant subsidies for project costs and project feasibility studies. This is meant to encourage the construction of regional systems that effectively utilize energy through large-scale cogeneration, which are to be one link in promoting a comprehensive energy policy.

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Table 2a. Public Financing

Organization	Application	Content
Japan Development Bank: Promoting gas air conditioning, introducing equipment to protect the ozone layer, and regional energy facilities in harmony with the environment	Cogeneration systems	Interest rate: 4.74 percent; Financing: 40 percent; Loan period: within 10 years (As of September 1, 1993)
Small Business Finance Corporation: Funding for alternative energy and for energy conservation	Cogeneration systems	Interest rates: 3.95 percent up to ¥270 million and 4.3 percent over that amount; Financing limit: ¥270 million; Loan period: within 15 years (defer for two years)

Table 2b. Preferential Taxation

System	Application	Content
Energy supply and demand structure; reforming the tax system for promoting new investment	Facilities supplying heat while generating power	Choice of either a 7 percent tax deduction off the purchase price (limited to 20 percent of the corporate assessment during that period) or 30 percent of the first year's special redemption. Application period: two years (April 1, 1992-March 31, 1994)

Facilities supplying heat while generating power are those operating generators, heat pumps or compressors with engines or turbines and utilizing the waste heat recovered for hot water, air conditioning, etc.

Toho Gas decided on a high efficiency gas engine heat pump system based on waste heat collection as an effective means for future development of a true cogeneration system, and commenced active development; the nation's first air conditioning and hot water supply system using a gas engine heat pump began operating at the New Maruiwa Hotel in 1982. The introduction of cogeneration progressed from that point on, centered around sports facilities (skating rinks and heated pools) and lodgings. At the present time there are gas engine heat pump systems operating in 15 establishments within our supply area for a total of 1,551 cooling (REITO) tons (excluding small GHP). This system is also attracting attention at the present time as a heat source for utilizing unusable energy.

At the end of fiscal 1992, there were 28 industrial establishments operating cogeneration systems, with 40,705kW, and 18 public sector establishments with 2,776kW, for a total of 46 establishments with a capacity of 43,481kW (Figure 1).

Fig.1

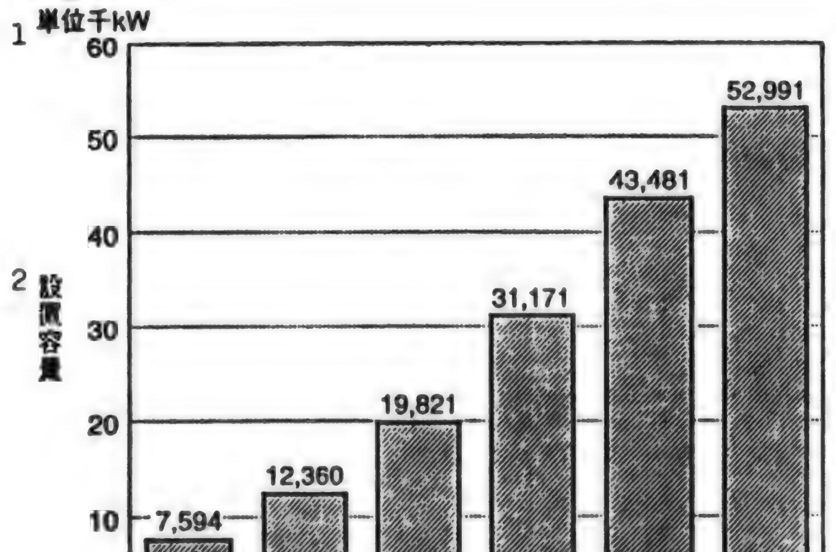

Figure 1. Record of Cogeneration Operation Over Time (based on end of fiscal year)

Key: 1. Units: thousands of kilowatts 2. Facility Capacity

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Fig.2

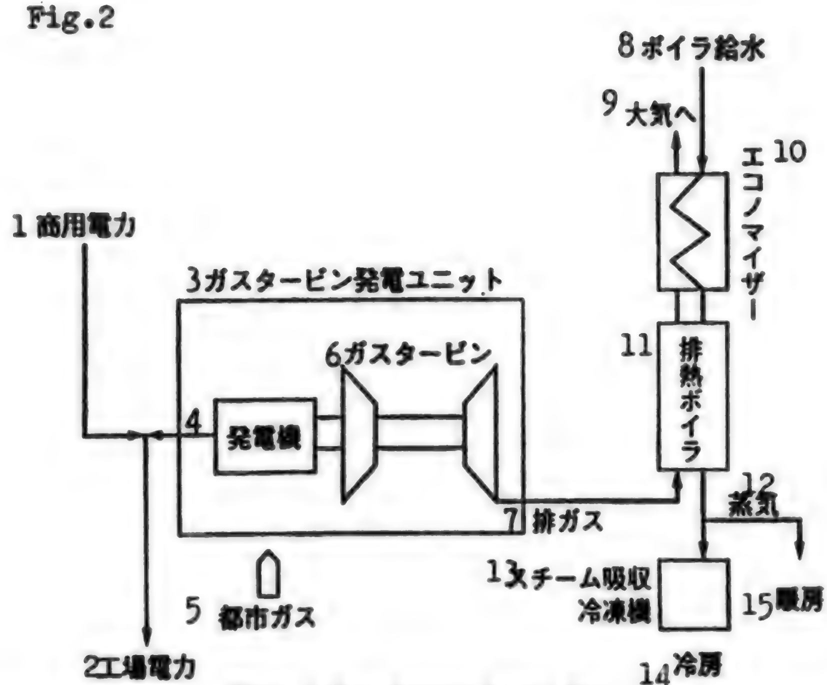

Figure 2. Sony Inazawa System Flow

Key: 1. Commercial power 2. Factory power 3. Gas turbine generator unit 4. Generator 5. City gas 6. Gas turbine 7. Waste gas 8. Boiler water supply 9. To the air 10. Economizer 11. Waste heat boiler 12. Steam 13. Steam absorption refrigerator 14. Cooling 15. Heating

The first cogeneration system our company introduced in the industrial sector was a 96kW system for food supplier Jasco's Chubu establishment. In a factory with a large heat demand needed for steam and hot water, cogeneration promotes efficient energy use. In many cases factories can make the most of cogeneration's advantages by combining a system with an absorption refrigerator. This can contribute to a no-freon policy for factory air conditioning and processing cooling, an industrial concern that is growing every year. Figure 2 is an example of the Sony Inazawa system used for air conditioning with two 1,500kW gas turbine generators (GP1500, a product developed jointly between Tokyo Gas, Osaka Gas, Toho Gas, and Kawasaki Heavy Industries) brought in.

In 1986 system linkages between the public sector and commercial power became possible, and in 1987 Toho Gas introduced the first system linkage cogeneration (200kW gas engine generator) in Nanzan University's athletic center. Furthermore, the preconditions for introducing cogeneration were provided, such as the "Expansion of Specially Designated Supply," which enabled the supply of power within that athletic center; after that, cogeneration was put in hospitals, sports facilities, and other public buildings.

Figure 3 is an example of the Sakae Gas Building's system, in which the power produced with a 350kW gas engine generator is linked to commercial power. Power is sold within the building (specifically designated supply) and steam, which is the waste heat from the regional air conditioning facility, is sent to the building.

Toho Gas Company's Efforts to Expand Cogeneration

At the present time, cogeneration is of great interest to our customers for industrial use and for air conditioning, and there have been many inquiries. Toho Gas suggests to the customer the following two points for an optimal cogeneration system:

1. Determine the most economical total system, for example with cascade heat use, based on the customers electrical load and heat demand patterns (overall economy).

2. In addition to the economy described above, select generation capacity and absorption water heater and cooler capacity that fits power consumption and heat demand and is also effective in reducing CO_2 and NO_x; that is, decide on a system that takes environmental compatibility into account (reducing the burden on the environment).

A recent trend that we strongly suggest for the industrial sector is a total system that requires the customer to reduce utility costs, conserve power, and reduce the load

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第3図 栄ガスビルのシステムフロー
Fig.3

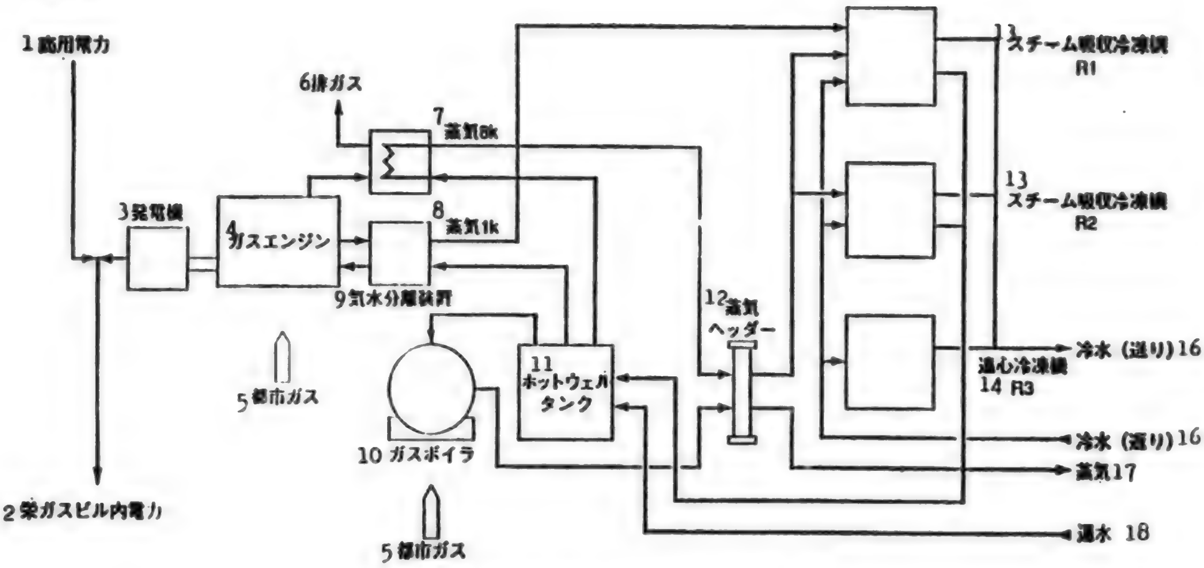

Figure 3. Sakae Gas Building System Flow

Key: 1. Commercial power 2. Power within Sakae Gas Building 3. Generator 4. Gas engine 5. City gas 6. Waste gas 7. Steam 8k 8. Steam 1k 9. Water separator 10. Gas boiler 11. Hot well tank 12. Steam header 13. Steam absorption refrigerator 14. Centrifugal refrigerator 15. Cold water (sent) 16. Cold water (returned) 17. Steam 18. Returned water

on the environment. For the public sector, we request that the customer construct a system that effectively utilizes energy by keeping the entire building or area in mind.

Within these parameters, we are working towards creating a structure that can suggest the optimal system based on the customer's needs, and towards establishing support for a technical backup and maintenance structure.

In terms of machinery, a gas power series (a joint project with Tokyo Gas, Osaka Gas, and gas engine and gas turbine manufacturers) is being developed. In terms of NO_x reduction technology, we are developing and selling air proportion control systems using oxygen sensors, and lean burn methods for operating engines with air in excess of that of the theoretical air-fuel ratio. We also intend to improve the reliability of cogeneration systems even more, and in addition to developing failure detection systems, we are developing technologies for lowering cogeneration costs, raising efficiency, and improving functions.

In terms of new technologies, we are aiming for even more efficiency and pollution reduction. At the present time development is continuing on items such as fuel cells, gas-driven diesel engines (gas-injection diesel), ceramic gas engines using new fuels, and stalling engines, which are external combustion engines.

Figure 4 is an example of the system at Nagoya Harbor Aquarium, in which a 100kW phosphoric fuel cell was installed for field testing.

Future Objectives

Customer expectations are high for natural gas, which has been designated a "mainstay energy" as a way to improve energy security, promote environmental support and energy conservation, and respond to the increasing demand for power. Expectations are also high for cogeneration, which is the best way to effectively utilize natural gas. In the future, Toho Gas believes that it must examine, together with its customers, just what an "effective energy utilization system" should be for a wide range of sectors.

For example, we wish to establish systems that utilize cogeneration's features to the fullest, such as "industrial repowering," in which a gas turbine run on natural gas is added to a factory's existing steam turbine, and a combined cycle is reconfigured; "refuse repowering," in which efforts are made to effectively utilize energy in waste processing facilities in order to save resources and energy, and "introducing regional heat supply cogeneration," which embraces regional conservation and environmental issues. At the present time, we have initiated a variety of simulations.

Moreover, in the last few years the government has been relaxing regulations on and establishing tax and public

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Fig.4

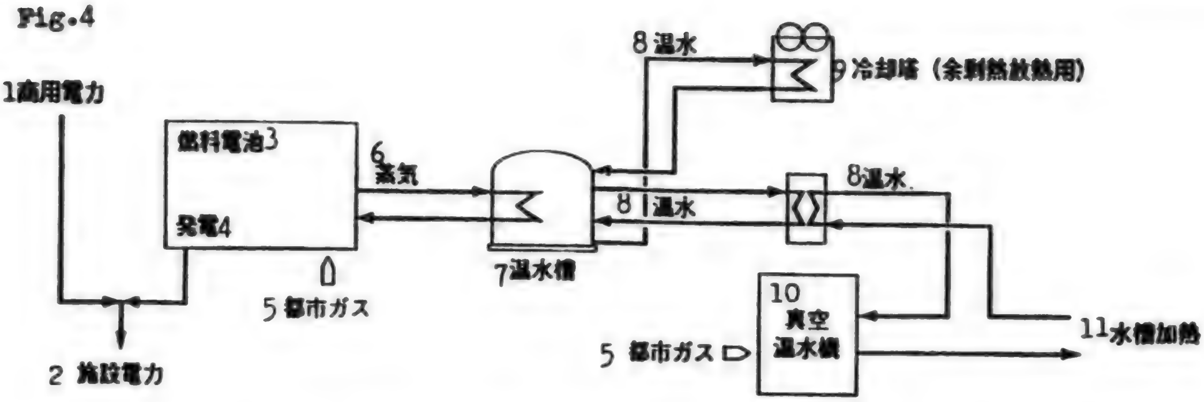

Figure 4. Nagoya Harbor Aquarium System Flow

Key: 1. Commercial power 2. Facility power 3. Fuel cell 4. Generator 5. City gas 6. Steam 7. Hot water tank 8. Hot water 9. Cooling tower (for radiating excess heat) 10. Vacuum water heater 11. Heating water tanks

financing aid for cogeneration, by providing guidelines for system linkages, expanding specially designated supplies, and establishing a system for purchasing surplus power. Another policy is facilitating efforts to promote projects like the Pro-Environment Energy Community concept and a regional heat supply system that utilizes unused energy.

Toho Gas will pursue future technological development of cogeneration based on the policies described above, and plans to tackle issues such as lightening the burden on the environment and improving reliability and economy.

MCFC Cogeneration and High Performance Heat Pumps Play Active Role in 21st Century City

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[Article by Mitsuo Fukushima, Research and Development Division Chief, Central Research Institute of Electric Power Industry (CRIEPI). Seventh of eight articles in the special issue on "City Gas Companies Putting Efforts Into Cogeneration"]

[Text]

Energy and CO_2 Cut to Two-Thirds or Less

An international city on the waterfront, where offices, hotels, and convention centers are active 24 hours a day. A future city employing 50,000 people, where "primary energy consumption and CO_2 can be reduced to two-thirds of present use." This is the result of joint research by the Central Research Institute of Electric Power Industry (CRIEPI) and Shimizu Construction Company.

If molten carbonate fuel cells (MCFC) and high performance heat pumps, which have been eagerly awaited as next-generation energy conservation technologies, are utilized to the fullest in 21st century cities, what will be the result? Quantifying the effect is one incentive for future research.

The 20th century is said to be the age of the giant city. As people concentrated in cities, Japan's urban population reached 77 percent of the total. As urbanization came to symbolize economic development, energy and resource consumption increased dramatically, and CO_2 emissions, the cause of global warming, increased as well. Consequently, the cities are eagerly anticipating new conservation and environmental technologies, for which energetic research and development are continuing through public and private cooperation.

Based on this awareness of the issues, an "Environment-Conservation City" was proposed at the CRIEPI-sponsored "Forum for Future Energy Technology" as the image of the city facing the global environmental age. The goal is to realize energy and resource conservation simultaneously with "Harmony between the city and the environment" and "City residents living together with the city's natural environment." Here, we focus on the role of MCFC cogeneration and high performance heat pumps as part of this goal.

Model of the "Environment-Conservation City"

A population of several tens of thousands is necessary for a socially and economically self-sustaining city. However, from an energy and environment viewpoint, we adopt a human scale city unit with a daily activity radius being within walking distance as the first step towards shaping the city image. This image stresses advanced business functions for dealing with the information age and international age, and is a "service-centered city" with sub-centers (Table 1, Figure 1).

This is a city of redeveloped coastal factory sites left after industrial restructuring, and centered around service and

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Table 1

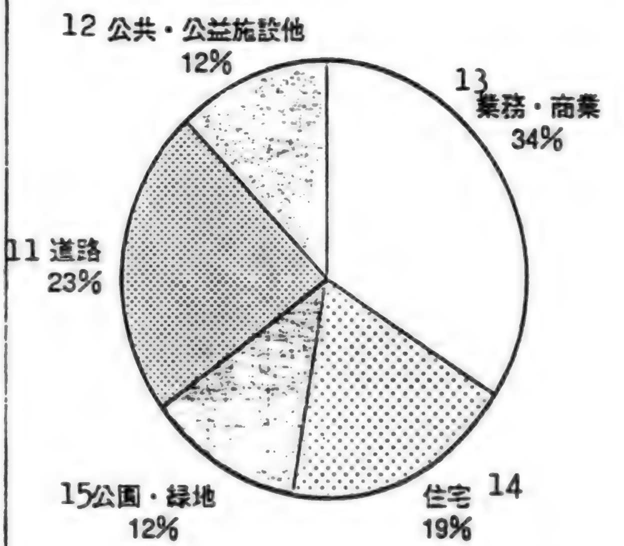
	1 業務中心都市
2 開発形態	再開発
3 位　置	巨大都市圏のウォーターフロント
4 性　格	24時間機能も備えた業務・商業中心，埋立地のリストラ
5 開発時期	21世紀初頭
6 開発面積	約130ヘクタール
7 従業人口	50,000人
8 居住人口	6,000人
9 住居数	2,000戸
10土地利用	

Table 1. Summary of the Environment-Conservation City

Key: 1. Service-Centered City 2. Development form: redevelopment 3. Location: waterfront in the vicinity of a major city 4. Character: centered around services and businesses providing round-the-clock functions; restructuring of reclaimed land 5. Development period: beginning of the 21st century 6. Development area: approximately 130 hectares 7. Employed population: 50,000 8. Resident population: 6,000 9. Number of houses: 2,000 10. Land use 11. Roads 12. Community and public facilities 13. Services and businesses 14. Housing 15. Parks and green space

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第1図 環境共生省エネ都市全体イメージ
Fig.1

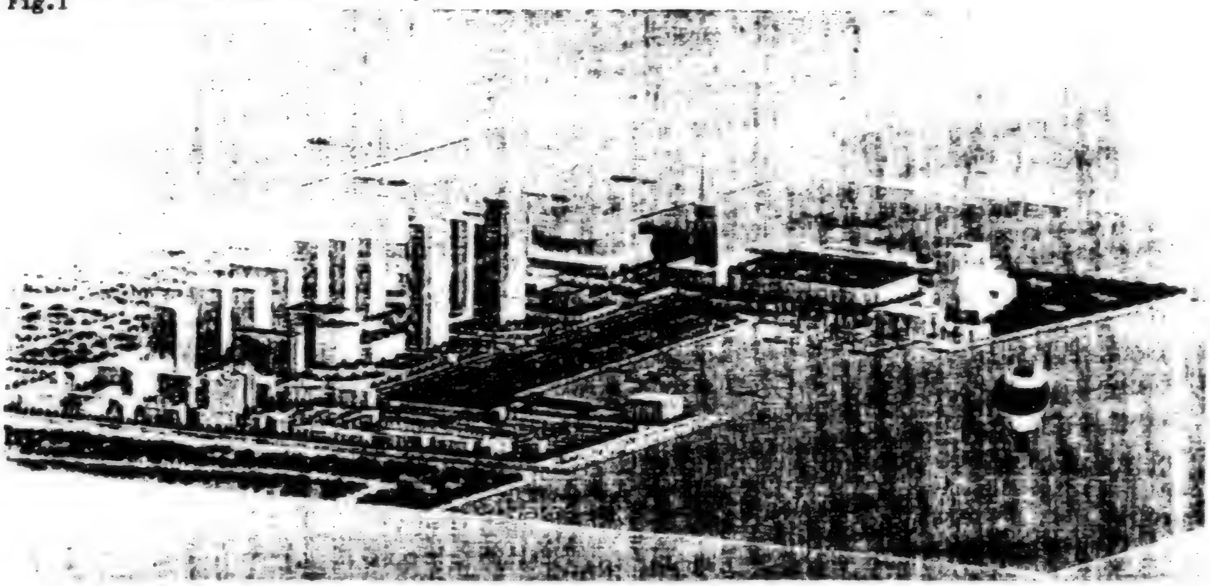

Figure 1. Total Image of the Environment-Conservation City

professional functions, which consists of distribution drawn away from the big cities and taking advantage of proximity to an international airport, the Asian base for multinational financial companies and the software enterprises supporting these hotels, trade centers, convention centers, and so on.

The total area developed is 130 hectares (Figure 2). This is somewhere between the Shinjuku Sub-Center (96 hectares) and the Yokohama Harbor Future 21 (186 hectares) projects in terms of scale.

Fifty thousand will be employed, but to give the area a sense of everyday life, and at the same time preventing a "ghost town" at night, one-fourth of the total area is guaranteed to be a residential zone, and a resident population of 6,000 is forecast.

In addition, a green and lush urban space is being created through a network of three-dimensional greenery on reclaimed land, rooftop gardens, and building walls, and the creation of various water projects such as man-made beaches, rivers, and fountains.

Conservation Technologies for the Demand Side

First energy demand was modeled using existing technology, with the value of heat and electricity demand per unit of floor space multiplied by the total floor space to find the value per building, and the number of buildings were then added together.

Then for the environment-conservation model, passive solar methods are adopted in construction plans for insulation, ventilation, and lighting, so that cooling demand is estimated to be reduced by 10 percent and heating demand by 50 percent. In addition, a 20 percent reduction in electricity consumption is proposed. As a result, total energy demand will be cut nearly 20 percent from current levels (Figure 3). Because there are a large number of offices, cooling demand is high.

Introducing MCFC Cogeneration and High Performance Heat Pumps

An energy supply system will be constructed adjacent to the river mouth (making it convenient to put unused energy to practical use) and under the exchange and exhibition zone, which is near the big business and commercial zone with its large demand (Figure 4).

Playing leading roles are the MCFC, which is highly efficient and environmentally superior, and the high performance heat pump which utilizes waste heat and sea water as heat sources. MCFCs, with a generation efficiency of 50 percent, will supply nearly 40 percent of this city's annual power consumption, 120 million kWh. Overall efficiency is estimated at 79 percent when heat use is included. Generation capacity will be 25 megawatts; this is because the load percentage is 50 percent even when demand is at its lowest, and generation efficiency is guaranteed to be 45 percent or higher. In addition, photovoltaic cells totalling 2.5 megawatts will be installed on half of the total roof area of houses and will supply one-fourth of annual residential power consumption, or 1.27 million kWh.

High performance heat pumps are expected to both heat and cool water, because air conditioning is needed even in winter for "intelligent buildings."

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Fig.2

第2図 環境共生省エネ都市のプラン

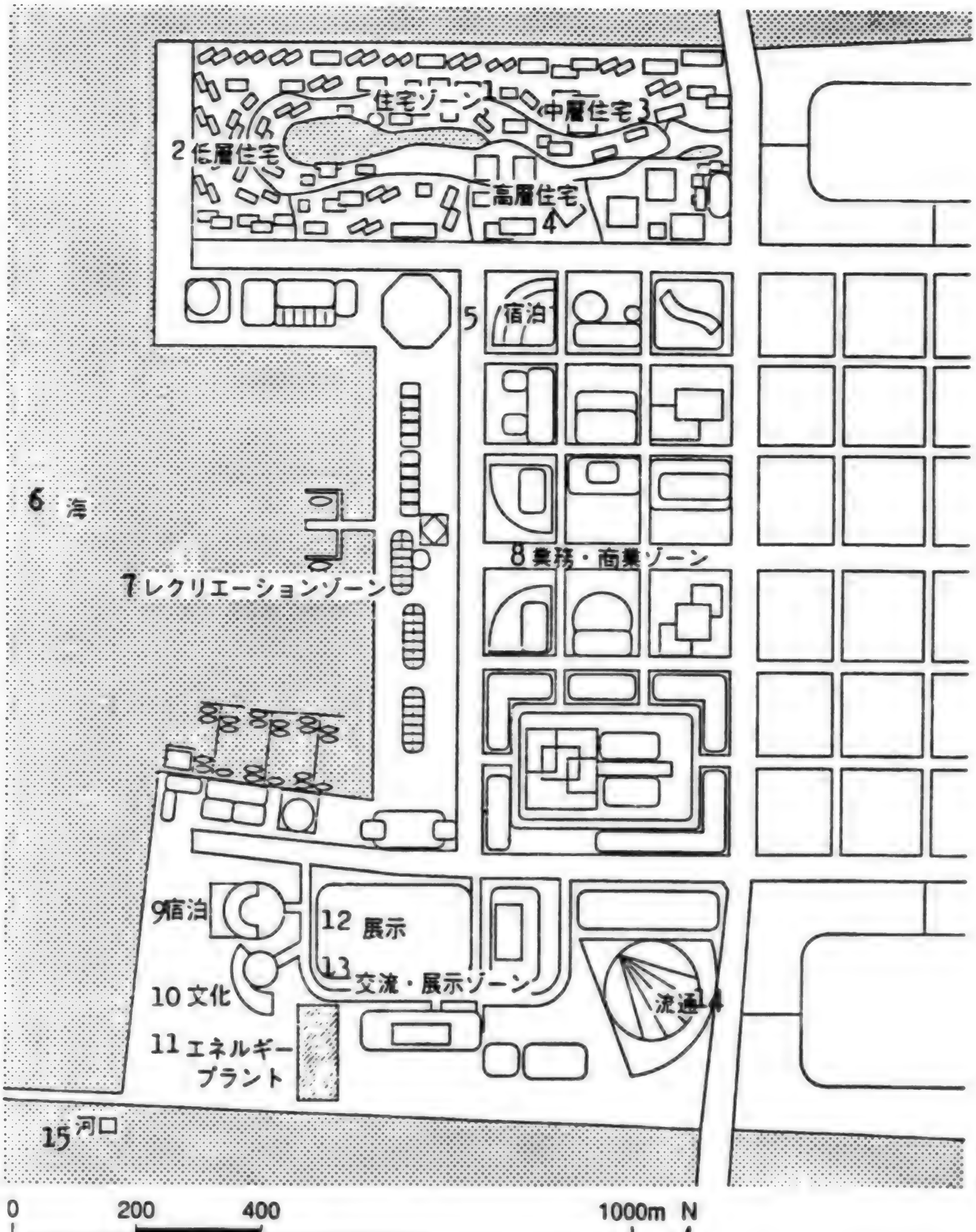

Figure 2. Environment-Conservation City Plan

Key: 1. Residential zone 2. Single-story housing 3. Multiple-story housing 4. High-rise housing 5. Lodging 6. Ocean 7. Recreation zone 8. Services and business zone 9. Lodging 10. Culture 11. Energy plant 12. Exhibitions 13. Cultural exchange and exhibition zone 14. Distribution 15. River mouth

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Fig.3

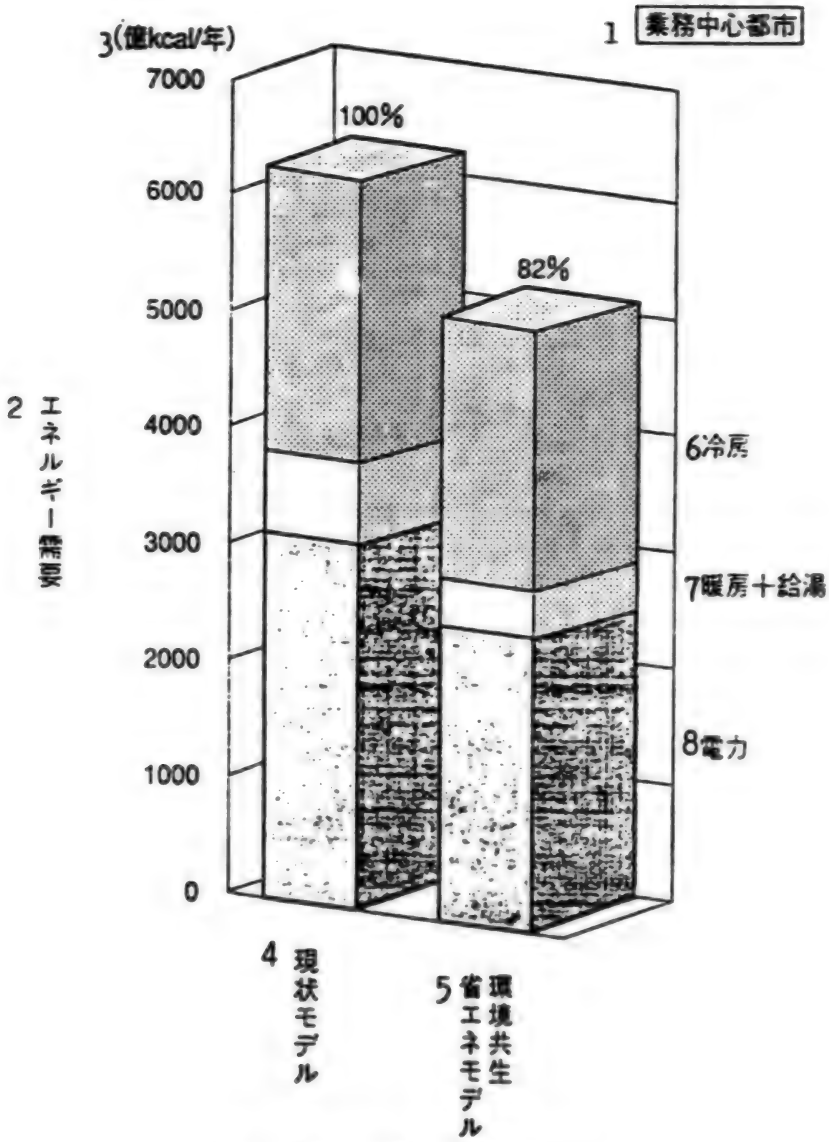

Figure 3. Energy Demand Estimates

Key: 1. Service-centered city 2. Energy demand 3. 100 million kcal/year 4. Current model 5. Environment-Conservation model 6. Cooling 7. Heating and hot water 8. Electricity

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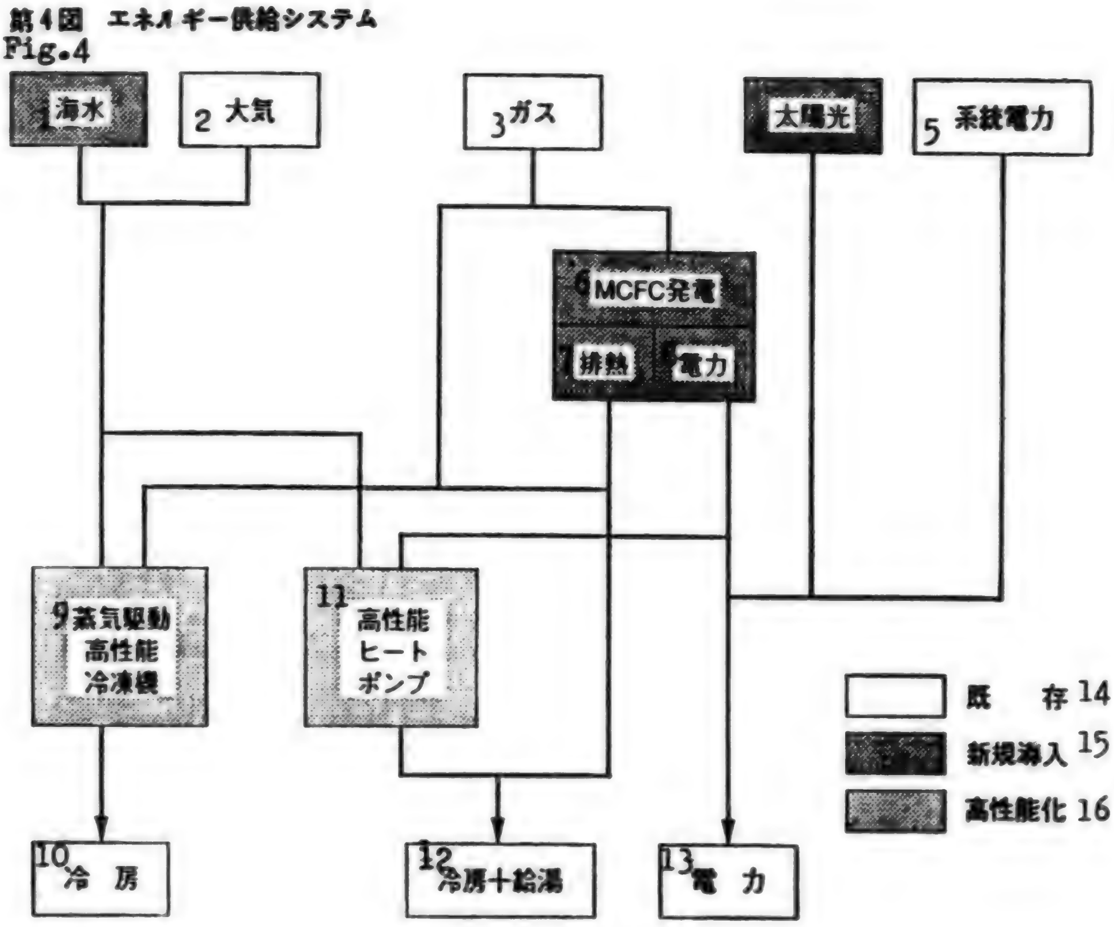

Figure 4. The Energy Supply System

Key: 1. Sea water 2. Air 3. Gas 4. Sunlight 5. System electric power 6. MCFC power generation 7. Waste heat 8. Electric power 9. Steam driven high efficiency refrigerator 10. Cooling 11. High performance heat pump 12. Cooling + hot water supply 13. Electric power 14. Existing 15. Newly introduced 16. Performance improved

Energy Consumption Simulations

To determine the energy consumption of a city in dynamic motion, the operation and stoppage of an energy supply system which responds to hourly changes in demand was simulated. In order to do this, the pattern of changes for the 365 days in the year, or 8,760 hours, were estimated based on actual data.

The results were as described above; primary energy consumption was reduced to 61 percent that of municipal systems constructed from past technology (Figure 5).

The 39 percent reduction consists of 18 percent, or about half, from MCFC cogeneration, 6 percent from utilization of high performance heat pumps, and the remaining 15 percent from energy conservation technologies on the demand side. CO_2, the cause of global warming, was also reduced to 64 percent due to the decrease in the consumption of primary energy.

In order to achieve "urban-environment coexistence" and "energy and resource conservation" simultaneously, we have shown that, beginning with MCFCs and high performance heat pumps, introducing new conservation technologies and environmental technologies is effective. Consequently, expectations for research and development are high, and as CRIEPI makes efforts to research technologies to support this kind of city, we have been fortunate in receiving advice and cooperation with regard to future directions.

Furthermore, the "Environment-Conservation City" proposed here should not be considered feasible as it now stands. Revisions in the social system are important issues as well, such as improvements in economy, easing of regulations, and fixed guidance policies. A variety of studies are also necessary, on topics such as, making homes and workplaces attractive, and disaster prevention.

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第5図 省エネルギー効果
Fig.5

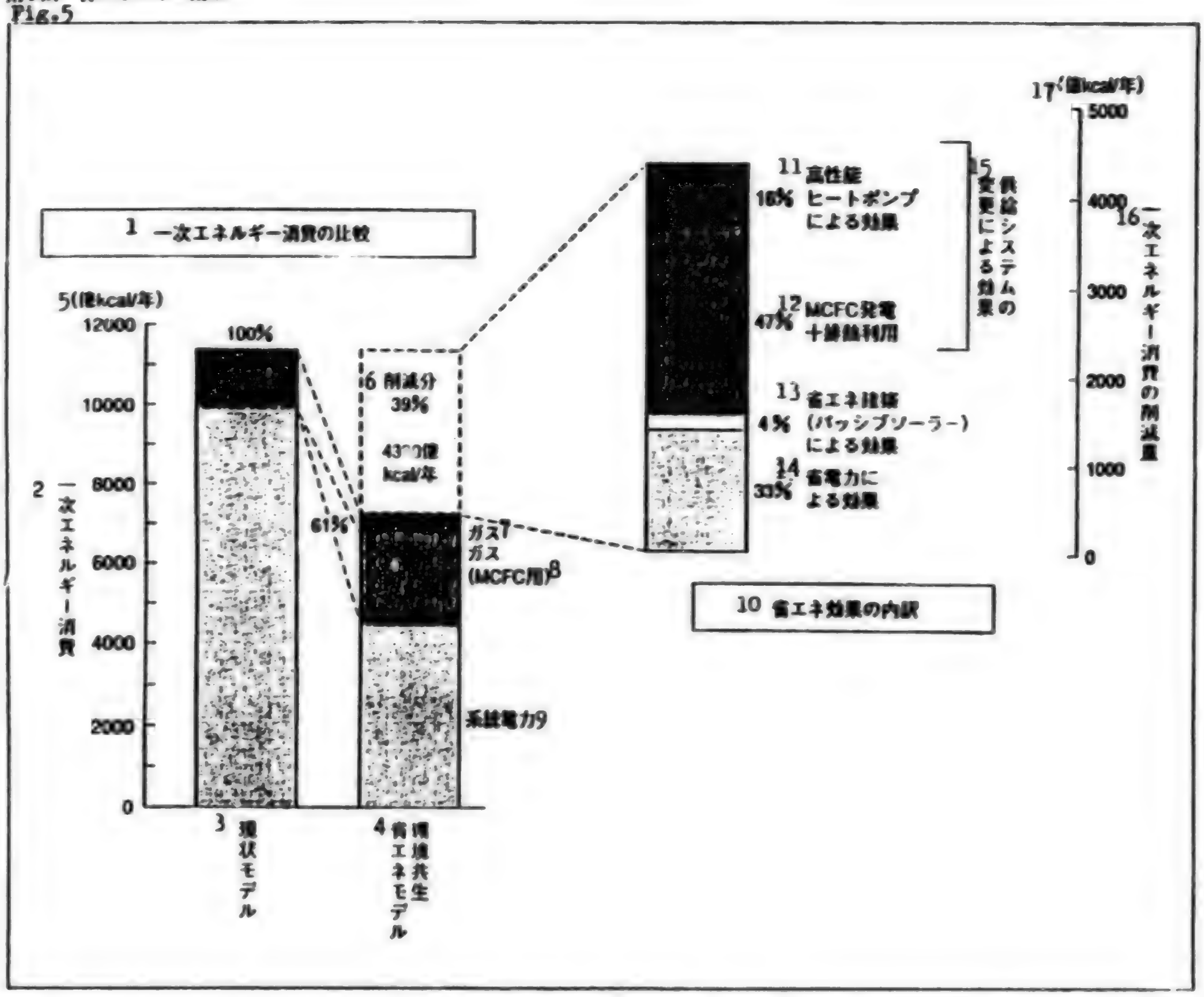

Figure 5. Results of Energy Conservation

Key: 1. Comparison of Primary Energy Consumption 2. Primary energy consumption 3. Current model 4. Pro-environment conservation model 5. 100 million kcal/year 6. Reduced 39 percent, 439 billion kcal/year 7. Gas 8. Gas (for MCFC) 9. System power 10. Breakdown of conservation results 11. Resulting from high performance heat pumps 12. MCFC power generation and waste heat use 13. Resulting from energy-conserving buildings (passive solar energy) 14. Resulting from conservation of electricity 15. Resulting from changes in the supply system 16. The amount of primary energy conserved 17. 100 million kcal/year

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Towards Popularizing Petroleum Cogeneration

94FE0480H Tokyo ENERGY in Japanese 1 Feb 94 pp 56-59

[Article by Nagaaki Kuroda, Senior Scientist, Business Research Section, Petroleum Energy Center (PEC). Last of eight articles in the special issue on "City Gas Companies Putting Efforts Into Cogeneration"]

[Text] The change in the national lifestyle due to the pursuit of "comfort" and "affluence" has caused an increase in public sector energy consumption. This trend is expected to continue, but because it conflicts with environmental problems caused by CO_2 and restrictions on petroleum resources, promoting total conservation will be necessary from now on.

As we attempt to stabilize the supply of petroleum-based energy, which is the foundation of Japan's energy demand, and work to maintain a degree of comfort in our living space, the need for perfecting efficient energy use is urgent. To realize even more conservation of energy, each piece of machinery must be made more efficient; where individual machinery has already attained a high level of efficiency, promoting the spread of total energy systems (TES) based on systematic ideas such as, multiple energy use and decentralized energy, and in particular promoting cogeneration, are thought to be effective.

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Based on this background information, the Petroleum Energy Center (PEC) has established a Cogeneration Society, and is in the midst of a five-year research and development project on "Pro-Environment Cogeneration," for developing petroleum cogeneration system technologies in order to improve overall energy efficiency and deal with environmental problems. PEC has also established the Petroleum TES Promotion Committee, which is expanding study and report activities on types of basic facilities in order to promote cogeneration; one of these activities is the development of a centralized petroleum cogeneration observation system. Here, we introduce the current conditions for petroleum cogeneration, and then introduce the research and development and studies described above.

Existing Conditions for Popularizing Petroleum Cogeneration

The demand for petroleum cogeneration was initially in the public sector, such as hotels, hospitals, sports facilities, health clubs, and leisure facilities, but it is now becoming widespread in the industrial sector, primarily factories. Recently, usage has increased for regional air conditioning applications and application of methods that combine unused energy and energy from refuse.

According to Japan Cogeneration Society data, 1,507 establishments had introduced cogeneration as of the end of March 1993, as shown in Table 1.

Table 1. Spread of Cogeneration Systems (from Japan Cogeneration Society data)

		Total cogeneration	Oil cogeneration (diesel engines)
Number of establishments	For public use	844	466
	For industrial use	663	365
	Total	1,507	831
Capacity	For public use	404,054kWh	244,574kWh
	For industrial use	2,101,243kWh	991,088kWh
	Total	2,505,297kWh	1,235,662kWh

Of these, the majority of establishments (831) have diesel engine petroleum cogeneration systems. Petroleum cogeneration for public use, by type of enterprise, is shown in Table 2.

Data: Japan Cogeneration Society (September 1993)

	Number of establishments	Output (kWh)
Hotels	140	77,198
Hospitals	28	20,422
Offices	49	41,053
Stores	65	41,589
Health centers	51	24,441
Sports facilities	45	34,682
Gas stations	72	4,662
Other*	35	15,273

*(schools, training centers, aquariums, health centers, research institutions, etc.)

Developing Technologies for Pro-Environment Cogeneration

Following basic and elemental research initiated in 1986, PEC implemented a five-year project, "Pro-Environment Cogeneration Systems R&D" in 1990. The main goal is striving for clean and efficient petroleum use; ultra-low NO_x diesel engines, catalytic cracking of NO_x for engine waste gas, and ultra-low NO_x stalling engines are being developed in order to achieve NO_x emissions of 110ppm, which is the metropolitan regulation. These research themes are roughly divided into the four topics below.

Ultra-Low NO_x Diesel Engines For Cogeneration

We are working on developing 200-500kW stationary diesel engines for cogeneration. We intend to improve combustion technology for the different types of diesel engines (impact diffusion, direct injection, variable rate of expansion, central sub-chamber, and pre-combustion chamber models) and to make the most of every aspect of combustion technology, such as delaying the fuel injection time, improving the shape of the combustion chamber, and rationalizing compression. While we clear the hurdles of raising thermal efficiency to 37 percent or better and reducing soot particles in exhaust to $0.1g/Nm^3$ or less for all the engine types, we intend to develop ultra-low diesel engines that can hold NO_x emissions to 220ppm or less (O_2: 13 percent).

While we clear the strict standard of 110ppm or less (O_2: 13 percent), NO_x for metropolitan areas such as Tokyo,

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Kanagawa Prefecture, and Osaka, PEC is continuing with research and development on engines that are compact in order to make installation easier and in which noise and vibrations are eliminated and the interval between overhauls can be prolonged to two years (16,000 hours). This is in addition to supplementary technologies for lowering combustion temperatures enough to suppress NO_x generation, such as water injection, immersion combustion, ventilation cooling, and exhaust gas recycling (EGR).

Furthermore, a six cylinder engine which can achieve the goal of 220ppm or less NO_x was installed in a generator at PEC's Basic Technology Institute at Toke, Chiba City, as a joint research project with the oil companies and engine manufacturers. Tests are now being run in order to ascertain the effects of moisture within the intake on the quantity of NO_x emitted, and to confirm parts durability and performance stability with reduced NO_x and soot and improved efficiency. Research is also continuing on installing EGR and testing at NO_x levels of 110ppm or less.

Systems for Eliminating Diesel NO_x With Catalysts

Here, we are working on developing catalysts with the goal of reducing the NO_x in exhaust gas by more than 50 percent and maintaining performance for 4,000 hours or longer.

Engine exhaust NO_x reduction of more than 50 percent for more than 2,000 hours can be achieved with a precious metals composite oxide catalyst, and while we are continuing tests for confirming performance stability over long periods of time, research is continuing on curtailing reducing agents and finding more active catalysts. We can establish chemical vaporization technology for the outer surface of zeolite series catalysts with a microgravity field, and verify the vaporization layer through surface analysis, and are currently evaluating the water resisting qualities of the Cu-ZSM-5 catalyst and examining types of carrier metals.

Systems for Eliminating Soot Particles With Filters

We are continuing research centered around elimination systems using catalytic filters; an elimination rate at the 95 percent level can be maintained for more than 1,000 hours, but the search continues for new catalysts with even lower reaction temperatures.

Petroleum Stalling Engine Cogeneration Systems

Research and development continue on a 30kW high efficiency, low pollution stalling engine cogeneration system fueled by kerosene, with the goals being 120ppm NO_x (O_2: 4 percent), durability of 4,000 hours or more, a heat load of 1 x $10^7/m^2h$, flame length of 20cm or less, and a turndown ratio of 1:10. Investigation continues on developing engine burners, high-speed response control methods necessary for systems, and high efficiency generators.

Research on Verifying a Centralized Observation System

By observing the operation of petroleum cogeneration facilities installed all over the country with a centralized observation center that can manage maintenance of regular operations, provide early warning when abnormalities arise, and explain the causes of and provide a quick response to those abnormalities, we can begin creating a new maintenance system for cogeneration. At the present time, the framework for this system has been completed, and a summary is given below.

System Configuration

As shown in Figure 1, a centralized observation system consists of sensors and data collection terminals installed in each facility, and personal computers for observation, workstations for diagnosing emergencies and for data management, and personal computers for FAX transmission installed in the observation center. Each function is described below.

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第1図 集中監視システム
Fig.1

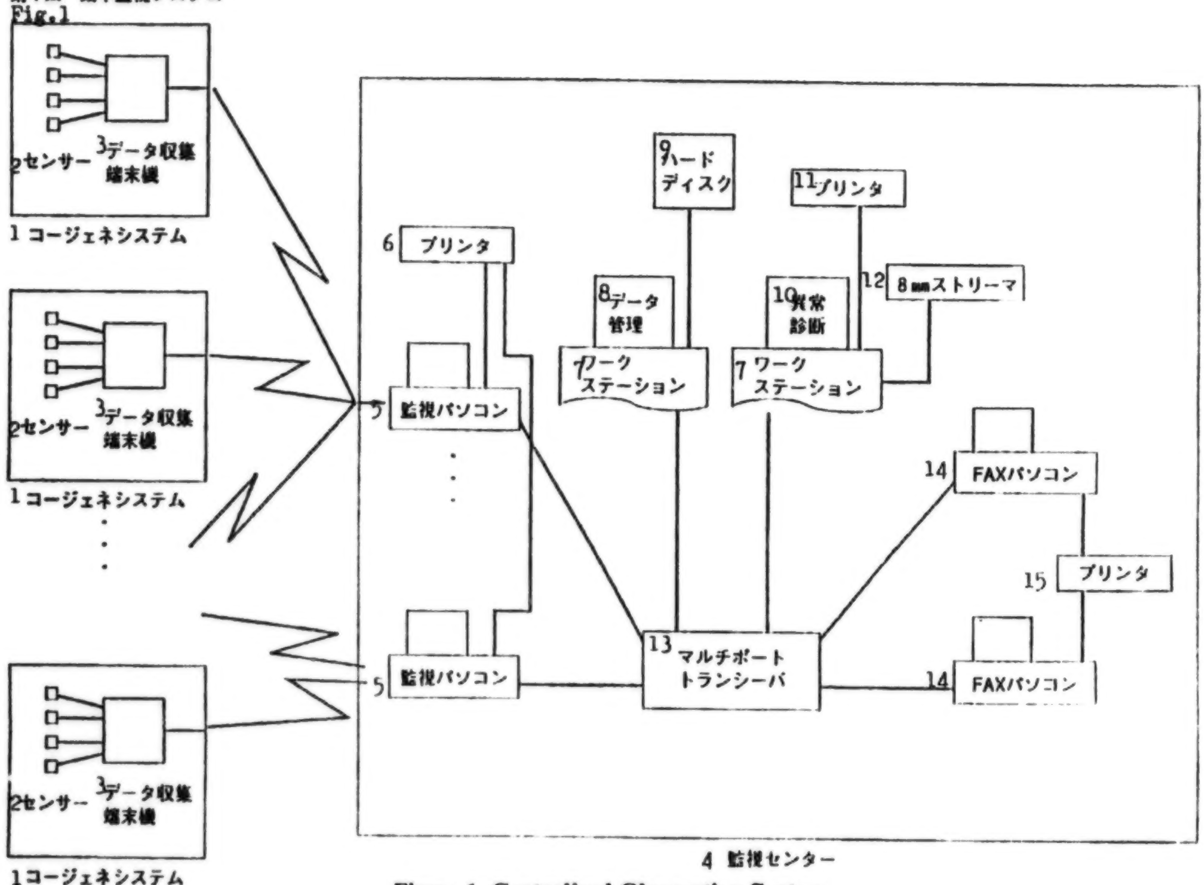

Figure 1. Centralized Observation System

Key; 1. Cogeneration system 2. Sensors 3. Data collection terminal 4. Observation center 5. Observation personal computer 6. Printer 7. Workstation 8. Data management 9. Hard disk 10. Diagnosis of abnormalities 11. Printer 12. 8mm Streamer 13. Multiboard tranceiver 14. FAX personal computer 15. Printer

System Functions

1. Sensors and data collection terminals: Data collection terminals consist of signal converters, data collection equipment, and models for communication, and store data obtained from 45 sensors and transmit the data at fixed intervals. In addition, they report an abnormality before established values are exceeded.

2. Personal computers for observation: Data transmitted from data collection terminals are regularly noted, and data received at regular intervals and at unusual times are forwarded to a data management workstation. These also create daily, monthly, and quarterly reports.

3. Data management workstation: The data sent from the observation computers are arranged by facility, type of data, and when the item was received. These are turned into a database in the hard disk, and can be looked up by data type or when received, and are analyzed with a general purpose spreadsheet.

4. Diagnostic workstation: When a problem arises at a facility, data on the abnormality is sent to the diagnostic workstation via the observation computer. When the abnormal data is received a diagnostic program automatically starts, and while the cause is being diagnosed, the results are collected and a file for FAX transmission is created.

5. FAX transmission computer: When a file for FAX transmission comes from the diagnostic system, it is automatically transmitted to the user.

In addition to the research and development and studies described above, the PEC is developing a petroleum total energy system and intends to popularize this. Research continues on developing fuel cells, high-efficiency machinery for public use, a project for studying models applying high efficiency energy systems, a study of basic equipment for petroleum heat pump systems, and a fixed interest grant project, through cooperation with oil companies and related enterprises.

Development of the petroleum TES and its dissemination will continue, and is expected to contribute to improving the environment.

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